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Chairman of the General Electric Co., Ltd.

President,
The Institution of Electrical Engineers,
1944/45.

Institution of Electrical Engineers.

INAUGURAL ADDRESS.

By SIR HARRY RAILING, D.Eng., President.

Delivered before The Institution, 5th October, 1944.

MY first duty in presenting my Address is to offer an apology and an explanation, the apology being for what is in effect an attempt to stimulate thought on the problems which confront our generation and clamour urgently for a solution, rather than an address upon some specific scientific or industrial problem.

When the call came to me to become President of The Institution, I felt on the one hand the great honour it conferred and the obligation it imposed, and on the other hand the impossibility of doing full justice to the task at a time when the first call on our profession and on the industry in which we are engaged still remains that of winning the war. It is only right that a President during the present crisis should explain his reasons for selecting a specific theme for his Address. I hesitated upon the choice of that theme.

Normally, an engineer would choose a subject upon which he is an expert. My own life has had three phases. I began with a thirst for research and development; later my lot was cast in the direction of practical engineering and production; later still, it became my duty to accept the charge of a great industrial undertaking. In these circumstances, you might reasonably have expected the new President to follow his personal predilection, one might almost say whim, and give you a lecture based upon either his first publication on commutators and characteristics of the arc, or upon a second publication dealing with the electrification of a Near East country as an example of the combined utilization of oil-, steam- and water-power stations. In either case a specific technical contribution to electrical science would have been the result. Instead, I feel that, however incomplete my contribution, it is more fitting that I should speak on the broad problems which the world has to face during this period of upheaval. Since engineers are held at least partially responsible for the difficulties through which we are passing, it is up to us to consider how far we can help to find the way out.

May I say here that I am fully conscious of the inadequacy of my own contribution. I offer only one excuse. It is that such an Address is usually written by a man who can retire from his normal occupation, at any rate for a time, to devote his whole energies to the task. In this year of crisis, whilst industry is still completely absorbed in the production of vital weapons of war, I cannot promise anything like a complete treatise. I can merely present the views of one whose life has been spent in engineering and industry, and try to assess the extent to which engineers in general and the electrical industry in particular can, and indeed should, contribute to the solution of some of the problems of the post-war era.

I have already referred to the charge made against engineers of bearing partial responsibility for this world conflict; it is said that we deliberately debased our thoughts and our efforts by devising machines which could be used for destruction. That word "deliberately" has a horrible implication. There is no need to tell this audience how unjustified it is. The light and warmth of the sun can be life-giving or life-destroying, according to the use men make of it, and the same applies to the aeroplane, wireless communication, and indeed to most of humanity's inventions. All life's potentials, all powers, physical or mental, are neither good nor bad in themselves. It is the use we make of them that renders them tools of progress or of destruction. Yet when we consider the tremendous, ever-accelerating progress made in engineering science during the last generation, we must come to the conclusion that while what we have learnt has been a definite factor in the general improvement in the conditions of human existence, it has also contributed to the catastrophe which has so nearly overwhelmed our own generation.

History reveals that every epoch of world-changing discoveries has been followed by world upheavals. When bronze replaced stone weapons and utensils, agriculture became possible. The invention of printing accelerated the spread of knowledge. In every case new tools have opened up hitherto undreamed-of possibilities for mankind, and boundaries hitherto existing between individuals or classes or between tribes have suddenly ceased to exist.

We engineers, and especially we electrical engineers of the 20th century, are responsible for a similar cataclysm; indeed, a greater one because our inventions affect the whole globe simultaneously. They have not been localized; they have not, as in past ages, spread gradually from one centre to another.

A discovery was formerly limited in its application by the number of men capable of developing it, by the difficulties of transport, and by the time involved in transmitting thoughts and experiences through written documents. Within a few years all this has been changed. We have annihilated distance and time as well. To-day Australia is nearer to England than Scotland was to London a century ago. A discovery made in London can be made available almost simultaneously in New York. We have put a girdle round the earth in considerably less than forty minutes. Furthermore, the number of workers on scientific and engineering problems has increased enormously. To-day, scattered all over the world, there are thousands, probably hundreds of thousands, engaged on scientific and technical problems.

The engineer has, from his discoveries, deduced certain natural laws. He has evolved new materials and new uses for old materials. He has made available the fruits of his labour, first for the few, then for the many; first in individual countries and then all over the globe. He has torn down the barriers between different civilizations, and has shown them new possibilities, given them new aspirations, incited them to new demands, given them new outlets for their thoughts and actions.

The progress has been so phenomenal, so satisfying intellectually, so helpful in raising the standards of living, that too little attention was paid to the fact that we had to develop and organize not only materials and sources of energy, but as well the lives of human beings. Humanity, indeed, should have been trained and encouraged simultaneously to accommodate itself to the increased impetus of science and engineering. Otherwise there would inevitably follow a disastrous piling up of pent-up energy, with the equally inevitable result, metaphorically speaking, of high impedance in the unprepared conductors, of violent oscillation surges and destructive breakdowns.

We ourselves should have foreseen more clearly these consequences. We should have made the world realize that our discoveries and their repercussions necessitated adjustments, the acceptance of new responsibilities on the part of every individual both to himself and to the community, and on the part of the various communities and States to each other. Insufficient appreciation of these facts was bound to produce new friction planes and violent disturbances, instead of an ordered steady progress on the part of units becoming more and more interdependent.

THE CONTRIBUTION OF THE ENGINEER TO THE WELL-BEING OF THE COMMUNITY.

It is clearly incumbent on us to realize the interaction between our life-task and world problems in general. A broader understanding of sociological problems has become essential for the engineer. His work no longer embraces only the use of materials and sources of energy; he has, as well, to understand and handle human beings. The products of his technical skill affect every human individual and every human organization. On the other hand, a greater understanding of science in general and engineering in particular has become essential for every citizen, not necessarily in the form of detailed knowledge, but indispensable for a better comprehension of life in all its aspects. In the logical pursuit of our mission to help the post-war world, we must therefore teach the principles which underlie our work, in the hope that they may be accepted and applied.

What exactly have we to teach? The first lesson arises from our training. In Engineering we begin by trying to discover the fundamental facts, before we draw any conclusions, or make a plan, or try to erect a building, or to construct a machine. Guided by experience and observation we establish and test these facts; we do not start with assumptions or build on imaginary foundations. Shakespeare says "Men believe easily what they wish to believe"; such beliefs are doomed almost inevitably to end in disaster. We test the facts under varying conditions, their uniformity, their variety; we establish their limitations; we draw conclusions, and apply them in successive steps, always taking into con-

sideration the means at our disposal and shunning universal application where variables apply. Having established and correlated our facts, we formulate what we term laws. Applying these laws, we tap new sources of energy, construct new machinery and devices, produce new materials. Fortified by experience we venture into the unknown, realizing that cause and effect are inextricably interwoven, that every potential produces a stress, that every action produces some positive or negative result.

Throughout, our mental attitude should be that of a seeker for truth. Integrity of purpose, disciplined imagination, and power of critical analysis form the essential basis. Access to the factual material available, together with knowledge of the scientific techniques at our disposal are, of course, indispensable. These alone can give that competence and confidence required to formulate any sound policy, or to come to any clear-cut decision; they alone can constitute what we term "scientific approach." This same approach, this same dispassionately scientific outlook, must be applied to life, to all its problems, to economics and politics, especially to-day, when our accelerated development affects every human activity, every national and international question. Its full meaning and value must be understood not only by a restricted guild, but by humanity at large.

The second lesson which we, as engineers, must teach is that we do not believe in a dogmatic approach to life, in generalizations, in labels.

The half-educated invariably tend to oversimplify. They do so through over-confidence in their small knowledge; they do not realize their own, or indeed any human limitations; they are mesmerized by generalizations, which do infinite harm by insistence on partial truths; they lack a sense of proportion.

We engineers are aware of our own limitations. We know that Nature is manifested in an infinite variety of gradations, that nothing is either wholly black or white, that elements are not immutable, that all types of variables produce different solutions, that every law functions only within definite limits, that all laws are no more than pictures representing the facts as far as we are cognisant of them. We are always prepared to change or modify our views in the light of added knowledge. The further we travel, the more conscious we become of the fallibility of our perceptions, the more we realize that we are finite and not infinite, and that however objective we try to be in our judgment, our objectiveness cannot be absolute. And from that knowledge should spring humility and tolerance for the opinion of others.

How much misery the world would have been spared if the scientific approach to all problems, the instinctive resistance to philosophical, political, and economic dogmatism and generalization, together with a spirit of tolerance for divergent opinions had been more common in our generation! How great a contribution we can make to-day towards the solution of every problem, and to the progress of mankind, by cultivating these qualities!

One could add minor points to these two great engineering principles. We have been taught to study differentials in our curves, and that, in living problems, means watching tendencies. We have been taught to extrapolate, which means predicting results from these tendencies, the rates of possible increases, decreases, saturation phenomena, interruptions, the value of curves showing steady progress versus oscillatory movements. We have been taught to draw conclusions from a number of known facts which we have proved by experience; we have also accustomed ourselves to advance by formulating hypotheses and subsequently proving them by a number of planned experiments. Identical methods are applicable to advance in all human problems.

In stressing these points I am far from suggesting that we are a superior race or class or guild, or that we have a monopoly of knowledge. I am only emphasizing my conviction that our knowledge and our methods, which are, of course, also employed in other professions, should be taught, understood and applied universally.

I have dealt with what we, as engineers, can contribute in general to the fundamental affairs of mankind. You may expect me to give you, as well, my views on some of the more specific contributions which we, and more particularly industry, can make towards solving international and national post-war problems. It is, of course, impossible in this Address to do more than touch very lightly on this task. It is obvious that the solution of each such problem depends on the objective and realistic application of the principles and methods of thought already mentioned. We must clearly see the facts, and on the basis of these and of the available experience, draw our conclusions.

We have to accept the following conditions. Raw materials are easily and increasingly

available everywhere; energy can be transported; machinery is also available, and labour can be trained everywhere. We cannot, in consequence, envisage either an individual or an organization within a country, or a country within the community of nations, which will be able in future to maintain any monopoly in production, unless—and then only for a short time—it can forge ahead in new developments and products, or can lead in quality or in production cost.

What proposals have been made to meet these conditions? The usual panaceas are offered, each of universal application, each guaranteeing a cure. They are on the one hand the nationalization of industry, and on the other extreme individualism and private capital; large-scale amalgamation versus extreme specialization; national and co-operative research versus individual research; greater attention to scientific management and planning by industry as a whole versus similar action by individual firms; high wages to develop the inland market versus the necessity to develop, and possibly subsidize, the export market in order to buy raw materials and food. Each remedy, taken by itself, presents a partial solution to our problem, in certain circumstances and within certain limits. Each one universally applied, regardless of its importance relative to the other basic factors and its interrelation with them, might prove no solution at all. It is for us to consider which remedies should be applied and to what extent.

Let us analyse some of these proposals particularly in connection with the position of the individual and the industrial unit *vis-à-vis* State-controlled enterprise.

It is to-day more than ever essential that every individual in industry should be as highly developed and receive as good a general education and training in his handicraft or profession as possible, and that he should be taught a deep sense of personal and collective responsibility. This means not only education in our calling, be it manual or professional, but in team work as well; and such education must stress the fact that anybody who accepts more from the team than he contributes, who seeks to take more out of life than he gives, constitutes a liability rather than an asset, while on the other hand every man who gives more than he receives creates values and therefore leaves something of a positive value to his fellow workers at the end of his career.

The individual industrial unit, even more than the individual engineer—to whom I shall revert later—must recognize the principle of team work and of give-and-take. The complicated industrial mechanism of to-day requires the co-operation of Capital, Labour and Management, even as it requires the co-operation of research, development, design and production. Success can be achieved only where there is active and willing co-operation between all these components. Where differences are over-emphasized, where selfish interests are stressed, where undue importance is placed on the rights or privileges or relative contributions, where demands are made which are incompatible with the existing state of affairs in similar competing units, friction will inevitably arise and energy be dissipated instead of being fully utilized for a common purpose. The progress of the whole unit will be obstructed, and each member will suffer with the unit as a whole.

It is essential for all to appreciate these basic facts. They have become of ever-increasing importance, and they are equally applicable whether capital be supplied by private enterprise or by the State. In either case capital, no less than labour, must be productive; in neither case must it be allowed to become a wasting asset. Only if the unit can produce greater values can there be more available for distribution, and if not enough capital, management or labour effort is forthcoming, the standard of return for every one of the three is bound to be affected.

Again, the total returns on capital, the salaries and wages—in other words the standard of living of each unit—tend to become more and more dependent on the conditions of similar units in our own and other countries. It will become a matter of ever-increasing importance, which must be realized by all classes of the community, that progress in standard of living, in security, in leisure, in all the things which every one of us wishes to achieve, whilst within certain limits attainable by the units alone, are bound to be limited ultimately by the standards of other groups in this country and abroad.

INDUSTRIAL ASSOCIATIONS

We now come to the part played by industrial associations. While the desire for individual freedom of action on the part of the unit has remained as strong as ever, it is now generally acknowledged that there is an ever-increasing volume of interests common to all members of a particular industry, the furtherance of which can be undertaken by such associations with great advantage both to the in-

dustry itself and to the market which it serves.

There is a danger that industrial associations, like so many other institutions and principles, may be assessed not on their merits, but on a partisan basis. Associations in themselves are again neither good nor bad; they may be either. Freedom of association is as essential as freedom of speech or freedom of conscience. We cannot enjoy freedom ourselves unless we grant it to others. The extremists on the one side stipulate that every industrial unit should be compelled to enter an association. I am personally opposed to compulsion. The extremists on the other side consider that every association constitutes in the end a restraint of trade, that it does away with healthy competition, and is contrary to the interests of the consumer and the community. Similar arguments could, of course, be used against all trade unions and all professional bodies. Properly constituted associations—and I know of no other in our industry—have all started on a voluntary basis; they have not laid themselves out to stifle reasonable competition, and have always given adequate representation to both large and small undertakings. They have made great contributions to ordered industrial progress, and proved themselves a socially beneficial instrument through such activities as the standardization of specifications and common parts, the pooling and exchange of patents and manufacturing experience, a measure of joint research, the standardization of trading conditions, the collection of statistical information, the maintenance of good relations with other industries, and negotiations with Government Departments and with labour. Experience has shown that the free agreement of members of an industry to discuss, investigate, solve and regulate these common problems on a federal principle, but without compulsion and without discouraging individual effort, is in the interest alike of their workers, their customers and of the country in general, provided always that the community has sufficient authority to ensure that no arrangements are made which are detrimental to other industries or to the community at large. This involves, *inter alia*, the right of the community to the compulsory use of patents under certain conditions, with safeguards to the inventors, and the right to approve national and international arrangements. If wisely managed, associations can have a great and beneficial influence on economic and efficient production, they can ensure steady employment, they can safeguard standards of quality, and they can prevent, or at any rate limit, industrial speculation.

INDUSTRY AND THE STATE

I come now to the position of industry within the State, starting from two premises which to-day are generally accepted. The interests of the individual, a group, or a class, must all be subject to the proven interest of the community. With this reservation, however, a community will be most successful, advance furthest, and obtain the highest degree of development, if it allows the utmost freedom of thought, action and development to the individual and to groups of individuals. The action of any central authority should be not so much to instruct people what to do as to restrain them from actions which might be prejudicial to others. In the past, industry in this country forged ahead through the initiative and the spirit of adventure of the individual. Most individual industries began in small units and developed into larger groups, acquiring in the process more and more a national conscience and a sense of responsibility—in short, a "utility-for-community" complex. In some other countries where industries started later and under different conditions, larger units, or even national industries, became the vogue. The dogmatic assumption that the one or the other solution is correct for all industries, in all circumstances, is wrong, as all dogmatism is wrong. Where a country is at the earliest stages of its industrial career, where no volume of managerial capacity is available, where individuality has to be built up, it is clear that the State may have to lend a hand. Later on, when enough individuality emerges and individual capacity becomes available, it may have to decentralize. Similarly we may have to curb excessive individualism and to counteract opposition to co-operation where such tendencies are anti-social.

There is no intrinsic merit in State industry merely because it constitutes the largest possible unit. There is no inherent advantage in either a large-scale or a small-scale undertaking. The size of the most economical production unit varies from industry to industry and product to product. There are units which are inefficient because they are too big, too impersonal and too unwieldy; there are others which are too small. The problem is to discover the most economical unit for a particular purpose at a given time, a problem which is constantly before us in industry. The solution depends on a number of factors—

on uniformity of markets, on capital charges versus labour costs, on the proportion of overheads to total costs, on the number of men who can be efficiently controlled by one management, on the diversity and flexibility of the manufacture of the products which we are considering. In specialized manufacture the size of the most efficient economic unit is often very small; in mass production and for capital goods it becomes of necessity larger.

The industrial development of our own country should, I consider, be upon these lines. The State should occupy itself only with matters of broad policy. Its function, decreasing in extent as we emerge from the immediate post-war period, should be:—

1. To co-ordinate general trade policy, trade relations and tendencies with those of other countries, especially the United Nations, in order to minimize as far as possible friction and consequent inefficiency.

2. To decide, in consultation with organized industry, the relative priorities to be given, as long as shortages exist in labour, raw material supply and new capital, always having regard to the needs and reconstruction programme of ourselves, of the devastated countries, and of the world in general. It is of vital importance that these priorities should be settled in closest consultation with industry, and that special attention should be paid to our export potentialities on a long-term basis.

3. To encourage, financially and otherwise, all measures which will induce industry to increase its efficiency, whether in the direction of scientific production and management, research and development of new markets and products, improvement in capital equipment, training and education of labour and of staff, long-term planning, or closing down of uneconomical units. I say encourage and advise, not compel. My main reason for doing so is that although progress may appear slower if dependent upon voluntary agreements and concessions, it will in fact be quicker if we avoid the increased resistance and opposition which enforcement is bound to evoke.

4. To encourage properly-constituted trade associations. Such associations should become the channels for discussion within industry and between industry and the Government when co-operative advice or co-operative action is required. The primary function of these associations should be to represent the interests of the particular industry with which they are concerned, while the function of the State should be to ensure that no association adversely affects the welfare and interests of the community.

5. To contribute to overall industrial efficiency by adapting the State's purchasing power and methods of taxation to meet abnormal fluctuations in employment of labour, thus preventing wastage of human and other national assets.

These I consider to be the functions of the State. Summing up as far as our manufacturing industries are concerned, at any rate at the present stage of our history—you will note that I am making the usual engineering reservation—I am of the opinion that a properly organized directive at the highest level is in the interest of the community. On the other hand, to use the State as the operating mechanism of productive industry in this country and at this juncture, would not in my view be in the interest of the community.

I have tried to indicate some of the fundamental principles which our profession has evolved from experience, and which consciously or unconsciously govern our life's work. I have tried to show that our first contribution must be to persuade the world that these same principles should be universally understood and applied to world problems.

Then I have ventured to discuss how, in the light of the new circumstances and facts which confront us, these same principles, this same outlook, should be applied to the broad problems of individual enterprise and co-operating units, and to the relations between State and industry.

PROBLEMS OF BRITISH INDUSTRY

I will now touch on a few—only a few—specific problems affecting in particular British industry. We have on the one hand countries like the United States with industries which can lay their plans on the basis of a vastly larger internal market than our own, and therefore on larger-scale quantity production, but who have to face a higher wage level than ours; on the other hand, there are other countries with the same or a smaller inland market and a lower wage level than ours. Our own standard of living and—since we depend on raw materials and food from abroad—our living itself, depend ultimately on the goods we produce and can use either internally or externally. Externally we can only exchange them because of their better quality or because of lower prices.

The doctrinaire, according to his particular creed, offers us one of three solutions. He will

say, you must always be ahead of others—this will solve all your problems; or he will stipulate that you keep your wages low in order to compete in the world's markets; or he will insist that you raise your wages so as to increase internal spending capacity, and thereby turnover. This is again a case where it is essential to weigh and evaluate the relative importance of each theory before coming to a conclusion.

It is clear that we shall have to try to keep any lead which we are fortunate enough to possess, with all the means at our disposal; in other words, by increased scientific research; by application of engineering knowledge; by development of efficiency in design and production, from both a mechanical and a psychological point of view; by planning ahead on a long-term scale; and by the exercise of vision and imagination. Since any advantages which we can achieve are likely to be both smaller and briefer than in the past, there is all the more reason to do our utmost to retain what is still within our reach.

As far as efficiency is concerned, there is one point which has become of ever-increasing importance in the changed conditions. The cost of a product depends, among other things, on the cost per man-hour; the cost per man-hour depends on the output and the wages per man-hour. Wages have largely increased since the war, and will be higher here for some time than in many other countries, provided we maintain our advanced standard of living. Our only chance to maintain that standard is through an increased output value per man, which in turn depends on the continuity of work, on the will to work of the employees and their understanding of the contribution they make, and finally on the capital equipment allocated to each man. Continuity of work depends on continuity of demand. The will to work depends on the one hand on a proper reward and proper working conditions in industry, and on the other hand on the ability to create an atmosphere of mutual trust and an understanding of the legitimate part played by each partner.

The engineer in the past has often been too deeply absorbed in his technology to pay sufficient attention to the fact that the creation of a conscious and happy team spirit within each production unit, and within industry in general, has become an essential part of his daily work.

The expenditure on capital equipment per man has become of ever-increasing importance. As wages rise, the ratio of interest and depreciation on capital equipment to labour cost simultaneously decreases. The value produced per man-hour can be greatly increased by a generous provision of capital assistance, provided always that the turnover is large enough to allow for such additional interest and depreciation. This is one of the most important factors among those which should be watched by British industry.

I now come to consider the influence of wages. It is, of course, basically correct to state that if wage rates in a country increase more than the normal cost of living, there will generally be an increase in the volume of articles produced, owing to an increase in the effective demand. It is equally axiomatic that with increasing wages, taken by themselves, the cost of the product increases, and therefore the quantity of goods which can be sold in the export market decreases, or alternatively there is an increase in the cost of raw materials and food bought in exchange. There is, therefore, a wage limit which, for a country like our own, cannot be exceeded so long as other countries lag far behind our standard of living. It is consequently of vital concern to us to-day that the living conditions of less advanced countries, especially those which have become industrialized, should approach our own, and so bring about an expansion of world demand and the possibility for us to advance further, or at any rate to retain our own standard.

You cannot improve the health of any class above a certain point unless you improve the general health of the community, and epidemics cannot be stamped out in any one country unless there is an improvement in the general health of its neighbours. This applies equally to standards of living, standards of security—in short, to all material and spiritual progress. The essentials needed to maintain the advance of British industry, therefore, are first, all measures that assure the maintenance of any lead we can gain by increased research, better education, and the development of the more complicated and advanced products; secondly, the provision of increased capital assistance for each worker, whether it takes the form of increased power supply, tool equipment, transport facilities, improved lighting, or working conditions in general; and thirdly, the enlightenment and education of management and labour, and indeed of every worker, both as regards his own contribution and that of each partner with whom he must work; finally, any measures which help to increase the volume

of our export business, and especially those which create expansion of world demand by raising the standard of living in backward countries.

In the end, the strength of any structure is derived from the strength of each component part. Ultimately, the sum total of all our contributions will always depend upon the individual, and upon the answer each one of us is able to give to the following questions.

How can we, on the one hand, realize and absorb what we call the humanities, and on the other hand make the community as a whole more conscious of the guiding principles of our profession, so that the engineer may become more of a philosopher and citizen, and the citizen, economist or philosopher more of a scientist and engineer?

Having accepted this ideal, how far can we, during the period of technical education, acquire the broad principles of our profession, the knowledge of raw materials, the knowledge of energy, the knowledge of handling and leading men? How can we get the best results from their efforts? Later in life, when we are forced to specialize, how far can we apply our knowledge with maximum effect to the specific problems on which we are engaged?

And lastly, how far, as individuals, have we retained an imaginative and adventurous outlook, and how far do we give expression to it in our work? The engineer's training teaches him to proceed logically and scientifically. But where there are no ready formulae available he will fall back upon his engineering power of analysis, on his own adventurous and artistic, or may I say creative, personality. He must be artistic, because, like every creative artist, he seeks to express, in word pictures and forms, the results of his personal experience. He should be adventurous because whilst safety within certain limits must be the foundation of all his work, it must not be over-stressed in the engineering industry, or anywhere else, or the spirit of enterprise and of high adventure will wither and die.

On the basis of the development of the individual and the encouragement of the maximum freedom of thought and action, co-operation within all the phases I have described, in industrial units, associations, nationally and internationally, can be built up.

Our outlook is at one with the outlook and the ideals of the British Commonwealth, where each unit is free to develop its own individuality, but where, by agreement, common problems are settled, not by compulsion, but by free discussion, under the influence of an overriding sense of responsibility.

As long as the intelligence and the sense of responsibility of the individual or the unit are sufficiently advanced to ensure that selfish consideration will not prevail where the welfare of the general community is at stake, this method of procedure in the affairs of mankind is clearly the one to be pursued. John Stuart Mill uttered a great truth when he stated that the worth of the State in the long run is the worth of the individuals comprising it.

Two major groups of impulses actuate mankind, the self-assertive or self-defensive, and the social or co-operative. As individuals and as communities we are endowed with both. It is therefore our duty to develop them both. We must ensure, however, that the first group enriches and does not obstruct, but helps, the second.

CONCLUSION

And now to sum up. For us, in the engineering profession, it is essential, especially now, when the necessity for specialization becomes more and more pressing, that we should realize fully the inner meaning of our work and have faith in it; that we should believe it is worth doing. In general, the engineer is conscious of this fact. He knows that, working with his hands or his brain, with the help of the tools he has discovered and created, he has made his full contribution to the material progress of every individual, and of mankind in general. He is providing opportunities for a broader life, for a richer life, for a life that extends to all classes of the community, to all races and countries. He is freeing man from toil that he may work for yet higher purposes. But the contribution does not end there. Knowledge is indivisible; science and technology are an integral part of it. If we believe in the principles which we apply in our own work, we must have the faith—nay, the burning desire—to apply them to life in general. Scientific thought grows more and more indispensable for the successful practice of the arts of life. We must insist on the same unbiased approach to all life's problems, the same abhorrence of half-truths and generalizations, the same recognition of individuality as in our daily work. We must persist in our constant unselfish seeking for truth, coupled with a humble realization of the limitations of all human knowledge. This I conceive to be an integral part of the life-task of every true engineer, and of the contribution required from him.

Electrical Progress and Development.

By H. W. RICHARDSON, B.Sc., M.I.E.E.
Editor of the G.E.C. Journal.

INTRODUCTORY

THE tremendous number of new applications of electricity to equipment and services necessary for the prosecution of the war is continually a subject of comment. But until the story can be told in far more detail than is yet possible, few can realise how far-reaching and original many of the new applications have been. In every branch of electrical research, development and manufacture, the Admiralty, Ministry of Supply, Ministry of Aircraft Production and other Government departments have made incessant demands upon the Company's resources; moreover, many of the problems successfully tackled have involved the design and production of specialised equipment and apparatus of a type not associated normally with the electrical industry.

The great volume of war work for which contracts were placed necessitated largely increased production facilities. Many new works have been built, and specialised Government factories were entrusted to the G.E.C. for management on behalf of various Ministries; in many cases the equipping of these factories was carried out so rapidly that most exacting production programmes were met.

It has been possible in the war time issues of this Journal to publish only an extremely restricted number of articles dealing with major new developments, but reference should be made here to the descriptions of valuable work leading to the production of diamond dies* and synthetic sapphires† and also to the rapid advances in the subjects of high frequency heating and infra-red heating.‡

The Research Laboratories at Wembley were largely responsible for these advances and, in addition, for scientific and development work covering the widest possible field; much of this work is still of a secret nature.

Of plant, equipment and appliances manufactured for direct war purposes one very important section included anti-submarine devices, degaussing plant for ships to protect them against magnetic mines, land mine detectors, bomb disposal equipments, and the like. Ranges of anti-aircraft appliances, such as predictors, height computers, receivers and so on were made in large numbers. Notable amongst airborne equipment which has been provided are generators of several types, auxiliary motors, instruments and gunsights; communication equipment has also been installed in large numbers of aircraft.

The whole subject of communications has been developed to an outstanding degree and radio receivers, transmitters and valves have been supplied for all Services in quantities vastly greater than the pre-war output. There has been great demand for cathode ray tubes due to the growing use of radiolocation, a subject in which great advances have to be recorded.

The need of efficient lighting for many new purposes and in many unusual situations has led to many new types of lamps, fittings and kindred apparatus. As many as 80 new types of lamps have been developed and produced for specific purposes, the most prominent of which is the 5ft. 80 watt fluorescent lamp to be described later in this article. Floodlight, beacon and lighthouse units for aerodrome service have been built, while the development of the Helmore lamp and the Leigh Light presented many problems which were successfully solved.

Of heavy plant designed specifically to meet war requirements mention should be made of aircraft carrier lifts and bomb and shell hoists.

A subject to which much attention has been devoted is that of electronics, and the great part which it has played during the war foreshadows the increasing extent to which it will be applied to electrical problems in post-war days.

* G.E.C. Journal, Vol. XII., No. 2, August, 1942, page 84
† G.E.C. Journal, Vol. XIII., No. 2, August, 1944, page 53
‡ G.E.C. Journal, Vol. XIII., No. 1, February, 1944, page 10.

Electrical equipment for commercial aircraft is another subject to which a great deal of thought will have to be given in post-war days. During the war valuable experience of the electrical requirements of such aircraft has been gained from the equipping of transport aircraft. There has been a demand for such electrical equipment as grillers, cookers, refrigerators, cabin heaters, kettles, toasters, ventilating fans, lighting fittings, electrically heated lavatory seats, constant hot water systems and radio sets.

Much plant and equipment has been exported to meet war needs, chiefly in British Dominions, but export trade in general has been regulated by Government policy. However, in spite of difficulties, the G.E.C. has maintained intact its vast overseas organisation, except in occupied territories, in anticipation of the great volume of export trade which will follow the end of hostilities.

It should be emphasised that the information in this article can deal only with a comparatively restricted section of the enormous and manifold activities of the war period.

TURBO-GENERATING PLANT.

Many large turbo-generating units have been built, prominent amongst which are a number for Russia to which further reference is made below. Of others, several 37,500 kVA, 3000 r.p.m. sets have been completed for C.E.B. stations and two for South Africa. Of seven sets of this rating which are now in hand, four are for the Meaford Station of the North West Midland Joint Electricity Authority, one for Kingston-upon-Hull, one for Woolwich and one for Newport Corporation. In some of the stations where turbo plant has been installed main switch and control gear schemes have formed a section of the contracts (fig. 1).

The rewinding of a 23,000 kVA turbo-alternator is of interest. Originally it was designed for 25 cycle generation but after rewinding for 50 cycles it is capable of supplying a load of 30,000 kVA consisting exclusively of traction rectifiers.

A large number of direct current geared turbo-generators has been completed for use on board ship ranging in output up to 1,000 kW. Four equipments for electrically propelled cargo ships include the necessary turbo-alternators to supply the propulsion motors of 6,800 s.h.p.

TURBINES.

A new system of governing for large H.P. turbines has been introduced, comprising steam control valves mounted on the turbine casing itself, thereby reducing the steam space between the valves and the nozzles to a minimum, with the result that there is less variation of speed with sudden and large

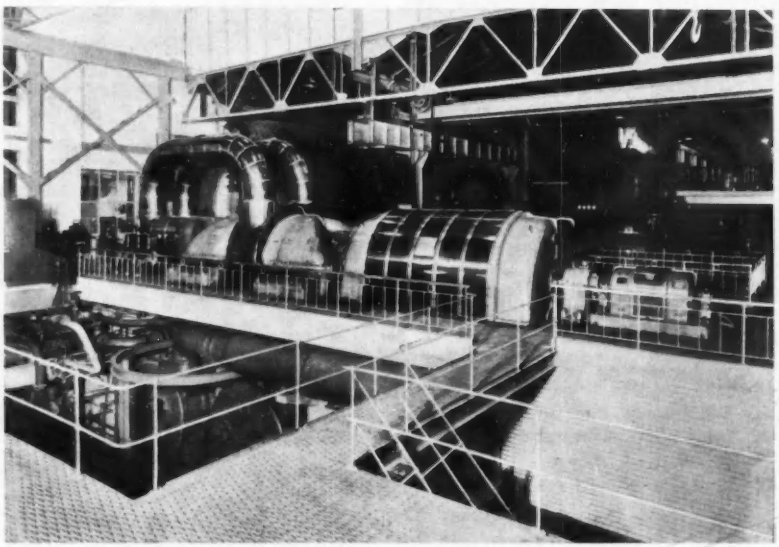


Fig. 1.—A 40,000 kVA, 6,600 volt G.E.C.-Fraser & Chalmers turbo-alternator in service at a Generating Station of the Stockport Municipality. In addition to the power unit, the equipment provided includes the main A.C. switchgear and the motors for the condenser auxiliaries.

changes of load. The pass-out governing has also been improved by providing complete compensation for any change in pass-out quantities and in load.

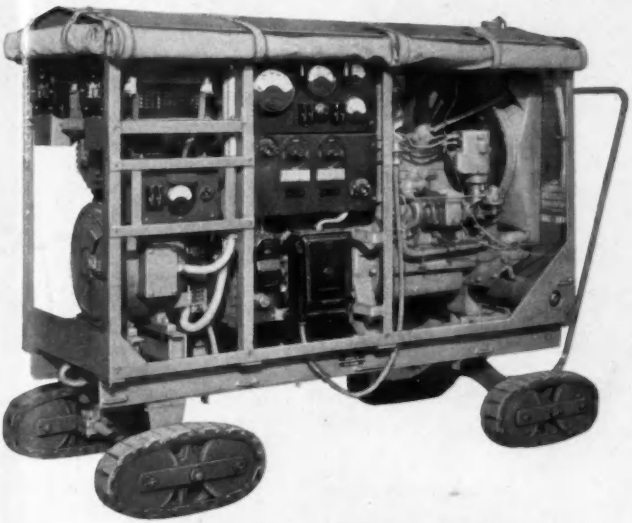


Fig. 2.—10 kVA and high frequency portable generating plant, including control board and automatic voltage regulator.

Both turbine and motor-driven blowers and compressors have been completed for several undertakings in this country as well as for export to South Africa. The first devaporising turbo-compressor has been put into commission in the West Springs Mines, South Africa, and its performance has been satisfactory in every respect.

The value of the new blading introduced a few years ago which embodies a varying reaction from root to tip of the blade has been proved by recent consumption tests on larger sets. The design of centrifugal turbo-compressors has been improved by the provision of more intensive cooling which has also led to increased efficiency, and a considerable amount of progress has been made in the development of gas turbines.

A noteworthy addition to the Turbine Works equipment is an electric furnace for treating turbine shafts at high temperatures and for rectification of faults.

HEAVY CURRENT GENERATORS.

Two motor-generator equipments manufactured for metallurgical plants provide a heavy current supply. In one equipment two D.C. generators each rated at 1,800 kW give a total output of 12,000 amps. The machines are turbine driven at 375 r.p.m. through gearing. The second installation consists of three D.C. generators with total rating 6,600 kW giving an output of 16,500 amps. at 35/400 volts. The machines are driven by a synchronous motor at 500 r.p.m.

PORTABLE GENERATING PLANT.

Great demands have been made for portable generating sets for Service use. Many large contracts have been undertaken, and a view of a typical set is shown in fig. 2. It comprises a petrol engine driving a 50 cycle and a 400 cycle alternator in tandem, the exciter being mounted on top of the latter machine and belt driven from a pulley on the shaft. The equipment includes a control board and automatic voltage regulators, and the whole is assembled in a framework mounted on four caterpillar tracks for road transport.

The 5 kVA electric generating sets shown in fig. 3 are designed to provide power for standard Army X-ray units manufactured by Watson & Sons (Electro-Medical) Ltd. A specially close automatic voltage regulator is incorporated. The complete equipment is mounted on Army lorries which contain also a dark room for processing the radiographs.

MERCURY ARC RECTIFIERS.

Reference could be made to numerous applications of the pumpless air cooled steel tank rectifier to both general and special requirements for war industry and transport.

Amongst the industrial applications, the performance of grid controlled 1,000 ampere pumpless units on electrolytic loads has demonstrated their ability to meet a heavy non-stop load maintained for several months at a time. Almost equally severe conditions have been encountered in other industries. As an example, a 4,000 ampere unit in the steel industry has maintained approximately 100 per cent load factor throughout the war.

On transport service three pumpless rectifiers each of 1,500 kW capacity have been successfully applied to main line railway electrification and fully automatic multi-unit substations installed for trolley bus working.

Fig. 3.—A batch of 5 kVA portable electric generating sets which supply power for Army X-ray units.

Mobile substations have maintained emergency D.C. supplies for various purposes including dockyard supply.

A typical pumpless air cooled rectifier substation is shown in fig. 4. It is installed in the Wood St. Sub-station of the Cardiff Corporation for supplying a municipal trolley bus system and contains four 250 kW rectifier units converting from 6,600 volts A.C. to 550 volts D.C. The operation is fully automatic and the equipment includes the main E.H.T. oil circuit breakers, rectifier transformers and D.C. board.

INDUCTION MOTORS.

The last few years have seen a good deal of relaxation in the rules of Supply Authorities governing the amount of starting current to be taken from the mains. In consequence many squirrel cage motors with outputs up to 750 h.p. have been made for direct-to-line starting. One particular application of these motors has been to the driving of ball mills.

There has been a tendency to use frame cooled induction motors of large output to a much greater extent than before, and in several instances these motors have been of the flameproof type.

EQUIPMENT FOR RUSSIA.

A very considerable quantity of electrical machinery has been supplied to Russia; this includes three 31,000 kVA and three 15,000 kVA turbo-alternator sets. Of particular interest is a number of 500 kW transportable power units embodying a turbo-alternator (fig. 5), switchgear and transformers. The alternator, exciter and feeder cubicles constitute a four unit sheet steel cubicle switchboard mounted on a common sub-base for transportation as a complete unit.

The G.E.C. has been res-

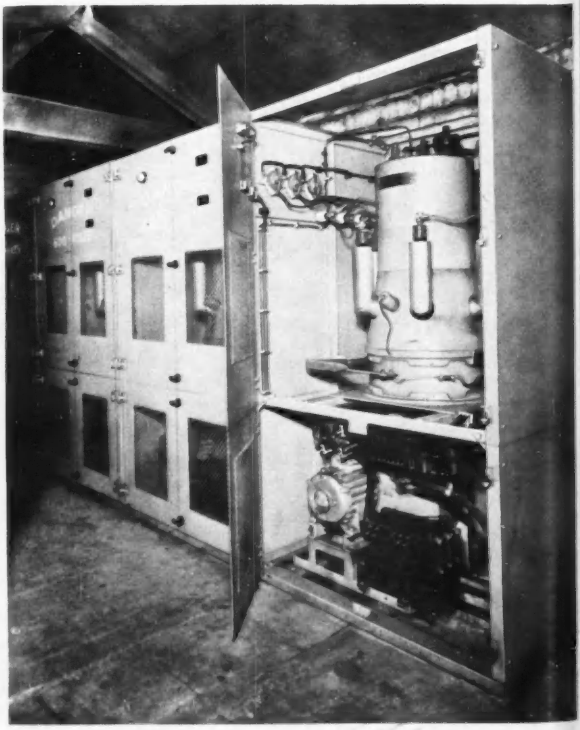


Fig. 4.—Four 250 kW rectifier units, installed in the Wood St. Substation of the Cardiff Corporation, supplying power at 550 volts D.C. for a trolley bus system.

ponsible for a complete power station for the U.S.S.R. beginning with the coal handling plant and finishing at the H.T. switchgear, the generating unit at present consisting of one 15,000 kVA turbo-alternator. The layout presents many features of interest and, as an example, fig. 6 shows the remote controlled boiler house switchgear.

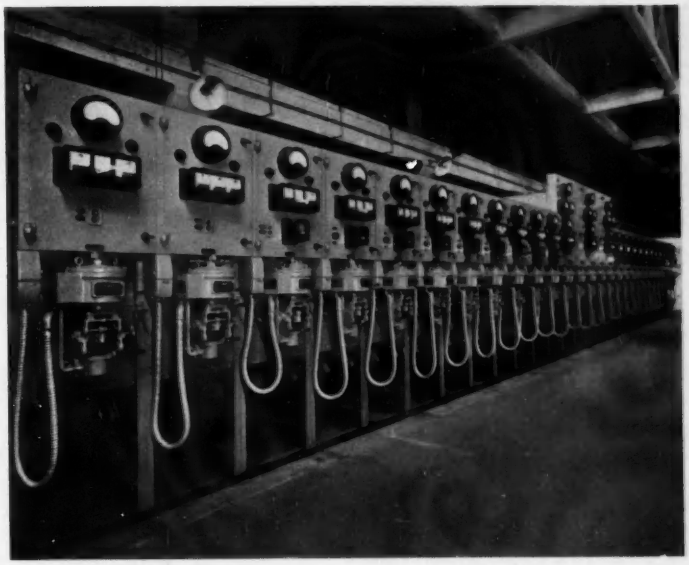


Fig. 6.—Switchboard controlling boiler house auxiliaries in a Russian power station.

For electro-chemical use three motor generator sets, fig. 7, have been built comprising a synchronous motor driving two D.C. generators giving a total output of 10,000 amps. at 230/280 volts; all the machines are forced ventilated through trunking in which air is circulated by a motor-driven fan.

A great number of motors has been supplied including a range of flameproof squirrel cage machines rated at 125 h.p. at speeds from 1460 r.p.m. to 730 r.p.m. One of these motors is shown at fig. 8.

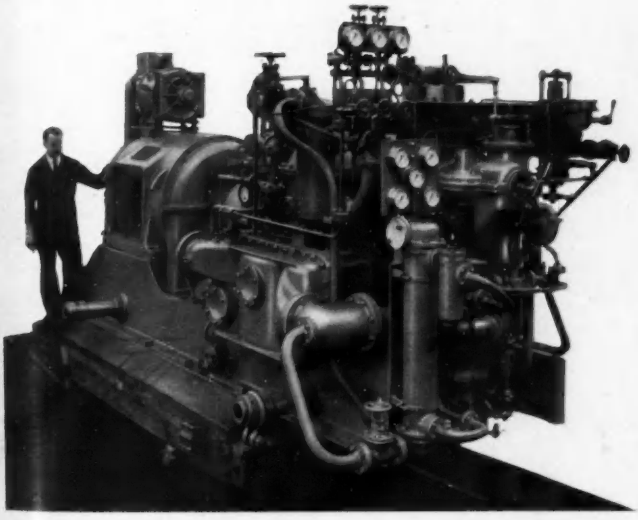


Fig. 5.—One of a number of 500 kW transportable turbo-alternators supplied to the U.S.S.R.

HIGH POWER SWITCHGEAR.

A new range of heavy metalclad gear embodying low oil content circuit breakers is available for all voltages from 6·6 to 33 kV, and for breaking capacities up to 1,500 MVA (fig. 9). The advanced design of the breakers and the use of condenser bushing busbars have enabled the quantity of oil and compound in the gear to be reduced to a very small amount. The system of vertical isolation of the circuit breakers combined with conveniently arranged interlocks and operating gear provides safe and easy operation. The circuit breakers used in the metalclad units have been adapted for both cubicle and outdoor mounting, while for 66 kV, low oil content outdoor type breakers have also been developed.

The range of metalclad "Subgear" has been extended by the addition of an 11 kV 250 MVA unit with oil immersed busbar selector switches, by means of which on-load or off-load busbar selection can be effected. Various improvements have been made in the design of

Fig. 7.—One of three heavy current motor-generator sets for the U.S.S.R. Each set comprises a synchronous motor driving two D.C. generators giving a total output of 10,000 amperes.

the range of "Subgear," particularly by the enclosure of the units and also by greater accessibility of the circuit breaker mechanism.

Designs of air blast circuit breakers for all common service voltages are being undertaken and an installation of 11 kV 350 MVA truck mounted breakers of this type has been completed for Kingston Corporation.

Many notable switchgear schemes have been undertaken; two of these are for British Dominions, one consisting of 36 units of 33 kV 1,000 MVA metalclad units for the Pyrmont Station, Sydney County Council, and the other of 150 "Subgear" units.

An important installation of stonework cubicle switchgear has recently been completed for Stockport Corporation and comprises 6·6 kV breakers of 750 MVA and 350 MVA breaking capacity.

FLAMEPROOF SWITCHGEAR.

A new range of flameproof mining switchgear (fig. 10) designed to meet the new draft Mines Regulations and certified at Buxton, is based upon a standard circuit breaker unit of very reduced dimensions, particularly in height. The unit is available for both H.T. and L.T. circuits and comprises a busbar pillar containing the isolating switch, current transformer, cable boxes, etc., and a wheel-mounted oil circuit breaker.

For use in conjunction with this gear a flameproof transformer of 500W capacity has been developed to supply lighting and other small amounts of power at low voltages.

In fig. 11 is shown a new design of gate-end panel which differs from earlier types in that it is divided into an upper and lower compartment. The upper compartment houses the busbars, the start and stop switch and a reversing isolator, by means of which the lower compartment may be isolated, without disturbing the supply to the remainder of a multi-panel board. The lower compartment contains a chassis on which are mounted the main contactor, overload and auxiliary relays, core balance current transformer, voltage transformer and condenser. The removal of four screws enables the chassis to be taken out or replaced in a few minutes; as sliding contacts are employed, the connections are not disturbed.

CARRIER CURRENT TRAP CHOKE COIL.

For use with carrier current transmission schemes on power lines, an improved wave trap coil has been designed. It consists of a coil of copper strip wound on edge and supported by a massive former of bakelised fabric. The tuning circuits are situated on top of the coil, the whole being housed in a bakelised paper cylinder the top of which is covered by a domed brass sleet hood. The

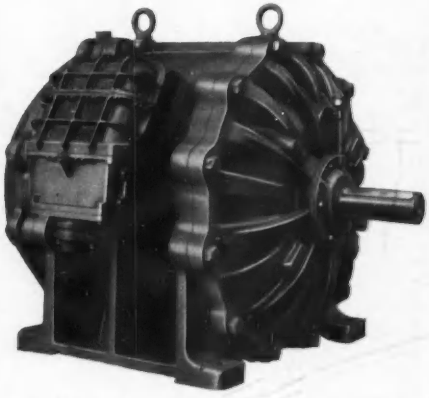


Fig. 8.—125 h.p. flameproof type squirrel cage motor for the U.S.S.R.

coil has been tested at 15 kA. It is suitable for voltages up to 132 kV and has an inductance of 208 millihenries; it will carry 400 amps. continuously.

SURGE COUNTER.

A surge counter has been designed to operate in conjunction with a lightning arrester and to provide a visible record of the number of surges passed by the arrester. Its action is entirely automatic and no auxiliary supply is required for its operation.

The counter, which is connected in the earth lead of the arrester, consists of a discharge unit in parallel with a condenser and a telephone type cyclometer counter. On the occurrence of a surge which is discharged by the arrester, the discharge current flows through the discharge unit; this causes a voltage to be impressed on the condenser which is substantially independent of the magnitude of the surge. So soon as the discharge current is interrupted by the arrester, the charge on the condenser flows away through the telephone counter, which thus records the passage of the surge on its dial.

IRONCLAD SWITCH GEAR.

Two additions to the range of double and triple pole ironclad switch fuses, rated respectively at 15 amps. and 20 amps., 500 volts, now make available a complete range of switch fuses from 15 to 200 amps. with fuse bases suitable for either rewireable fuse carriers or carriers to take H.R.C. cartridge fuse links.

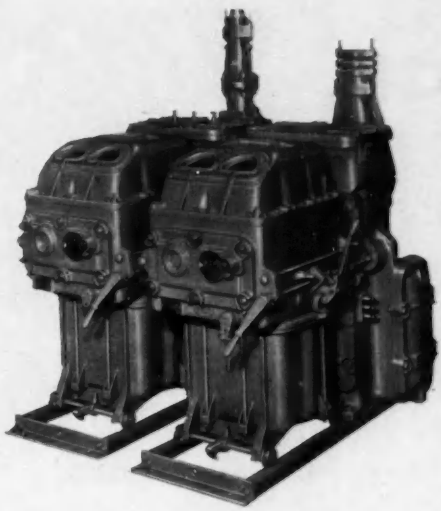


Fig. 10.—Two units of the new flameproof oil-immersed mining type switchgear.

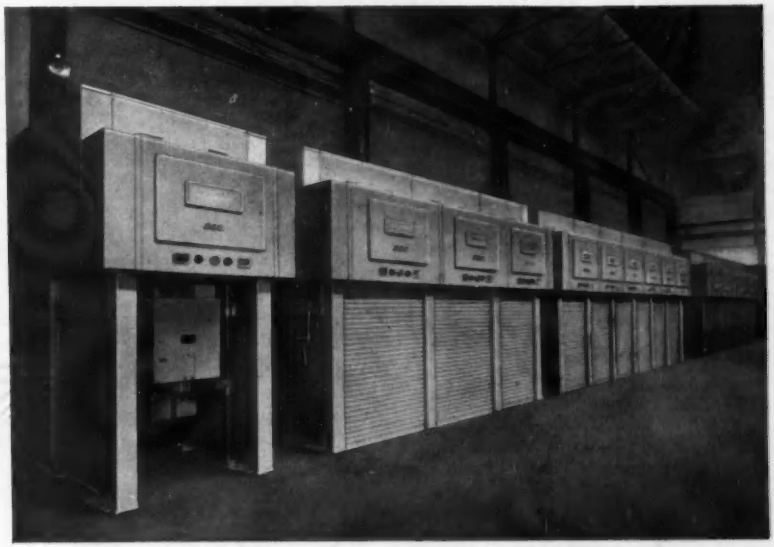


Fig. 9.—16 Units of 33 kV heavy duty metalclad switchgear, being part of a contract for Sydney County Council.

Fig. 11.—Automatic flameproof gate-end panel with cover removed to show details of the chassis.

There is now available a new range of 20 amp., 500 volt ironclad distribution boards with 2 to 24 double pole ways and 2 to 12 triple pole ways, with or without neutral ways, employing the universal type of fuse unit having a base suitable either for a rewireable fuse carrier or a carrier for a H.R.C. cartridge fuse link. Single pole and neutral boards in this size are also available with 4, 6, and 8 ways.

PORTABLE MINING SUBSTATION.

A range of portable mining substations with ratings from 50 kVA to 250 kVA complies with all current Mining Regulations. Its design takes into account also the new draft Mines Regulations, in particular where they relate to the exposure of live metal to atmosphere and to the total oil quantity, which is below 50 gallons in sizes up to 200 kVA.

The substation (fig. 12) is a self-contained unit comprising a transformer with flameproof high tension isolator, low tension circuit breaker and flit type cable boxes. The complete unit has very small overall dimensions so that it may be transported easily below ground.

The high tension isolator and the low tension circuit breaker with flit cable boxes are independent units, each of which is Buxton certified.

AIRCRAFT VOLTAGE REGULATORS.

Important technical development work was involved in connection with contracts for a range of voltage regulators for airborne equipment. The manufacture of these units called for precision work with very fine tolerances. There were, in all, 10 types of these regulators covered by the contracts and about 100,000 regulators have been delivered.

WELDING.

The major demand during the last few years has been for static welding plant, and both single and multi-operator welding transformer sets have been produced in large numbers. Portable single-operator sets have been supplied mainly for lighter work and purposes of repair and maintenance. Multi-operator sets have been installed notably in shipyards and undertakings concerned with heavy constructional work. At fig. 13 is shown a section of such a Works where multi-operator plant provides current for 110 welders.

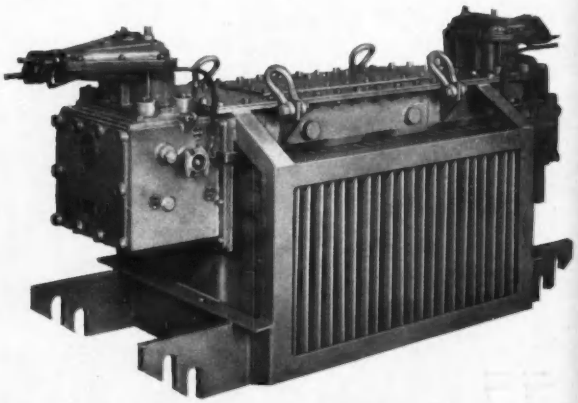


Fig. 12.—125 kVA portable mining type substation from the H.T. isolating switch end.

The range of multi-operator welding transformers provides for 3, 6, 9 or 12 operators. Special precautions are taken to provide the maximum protection against accidental damage and all windings are strongly braced to minimise vibration and consequent chafing of insulation. The transformers can be made up into complete power units by placing the

Fig. 13.—Arc welding of prefabricated components in a large Works. The equipment comprises 23 transformers supplying over 100 operators.

main A.C. switch on the side of the tank and mounting a condenser for power factor correction on a common base with the transformer, fig. 14. The primary switch referred to above is fully interlocked and is fitted with H.R.C. fuses complying with the requirements of B.S. 1071.

The individual regulators used by the operators are each fitted with a main current selector and vernier type regulator.

The downward pointing self-draining plug entries are most suitable for outdoor use.

A complete range of auxiliary equipment has been developed comprising distribution boxes, paralleling devices, cable couplers, etc. The distribution box is fabricated of steel to render it suitable for the rough conditions associated with the yards and workshops where heavy welding operations are frequently undertaken.

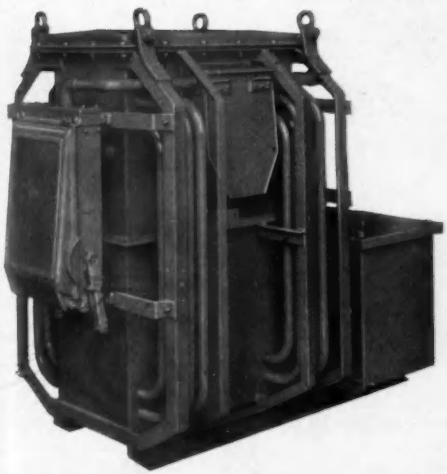


Fig. 14.—Multi-operator welding transformer and power factor correction condenser mounted on a common base.

ROLLING MILL ELECTRIFICATION.

For the complete electrification of a new reversing mill for Birmetals, Ltd., Birmingham, there has recently been installed a 1,600 h.p. D.C. reversing mill motor 51/0/51 r.p.m. supplied from an Ilgner set, the peak load attaining 3,800 h.p. (fig. 15). A particular feature is that the run-out tables are controlled with the mill so as to conform accurately with the speed of the material entering and leaving the mill at each pass. Rapid reversal of the mill is effected by forcing the field of the generator under the control of a speed balancing relay. The coiling and slitting line, for the operation of which 12 motors of varying ratings are employed, is designed so as to permit the material either to be coiled or cut into sheets, the actual cutting being effected in both cases by a flying shear.

A further installation, at Whitehead Iron and Steel Works, South Wales, concerns the equipment of a strip mill where an 800 h.p. 500/800 r.p.m. motor drives the double-ended reversing mill, together with two 150 h.p. motors for the coiler equipments. The scheme provides for constant-tension coiling and uncoiling, and full compensation is

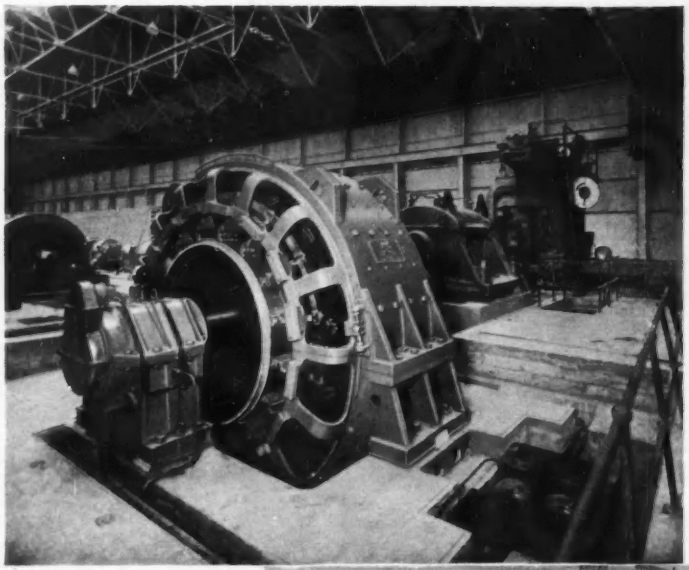


Fig. 15a.—(above) Reversing mill installed at Birmetals, Ltd., Birmingham, with 1600 h.p. D.C. mill motor (3800 h.p. peak load) 51/0/51 r.p.m. supplied from an Ilgner set.

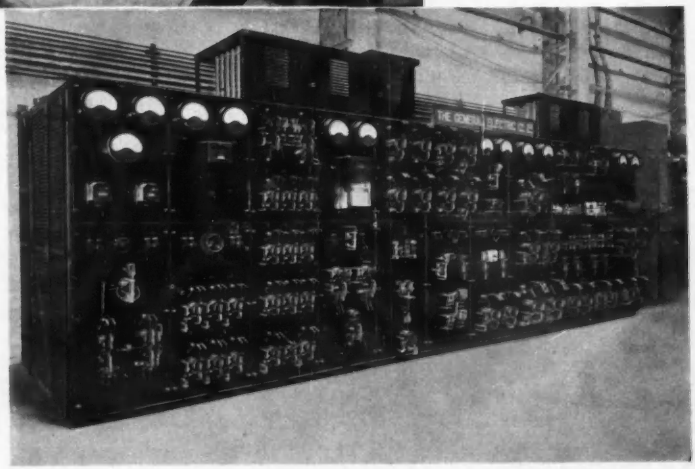


Fig. 15b.—(right) Automatic contactor control board for controlling generators, exciters and mill motor.

achieved automatically under changing speed conditions by the use of an electronic controlling device. The manual control is centralised at a desk situated near the mill stand, giving the operator complete command of the operation of the mill. The associated contactor panels are separately housed in a nearby substation, affording them the advantage of operating in good atmospheric conditions. A 200 h.p. 400/1,200 r.p.m. motor drives a skin pass mill.

A slipring induction motor of unusually large diameter has been supplied for driving a cogging and intermediate mill. It is rated at 1,000 h.p., 11 kV and runs at 200 r.p.m.

A high duty contactor for D.C. rolling mills has been designed and supplied for 50 operations an hour with a continuous rating of 2,500 amps., but capable of opening and closing 6,000 amps. and having a rupturing capacity of 10,000 amps.

COLLIERY AND MINE ELECTRIFICATION.

An existing Ilgner controlled D.C. winder of 1,200 h.p. in the Brookhouse Colliery of the United Steel Companies, Ltd., near Sheffield has been modernised by the addition of a new system of control which limits the magnitude of the current which can flow between the motor and generator under all conditions of working.

There has been an increasing use of salient pole synchronous motors for driving compressors, fans and similar equipment; a typical drive is shown in fig. 16. This installation is one of a number for The Amalgamated Anthracite Collieries, Ltd., South Wales. For a similar type of drive in a South African mine a 1,500 h.p. 2,200 volt, salient pole synchronous motor running at a speed of 120 r.p.m. has been supplied.

MARINE ELECTRIFICATION.

The tremendous volume of work undertaken for the Admiralty will be described at a later date, but reference may be made to certain work for cargo ships. The most outstanding

contract in this category has been for the propelling and auxiliary equipment for four cargo vessels. The main items for each ship comprised a 6,800 s.h.p., 115 r.p.m. synchronous propelling motor (fig. 17), the complete propulsion control equipment, a 5,300 kW, 3,100 volt turbo-alternator running at 3,000 r.p.m.; also a 400 kW, 220 volt D.C. geared turbo-generator for supplying auxiliary services, and many auxiliary motors and starters.

The main sections of the propulsion control equipment are (1) a high tension cubicle housing the main reversing switch and protective apparatus and (2) a control desk carrying the hand lever controlling the H.T. reversing switch, the hand wheels actuating the turbine governor setting and various switches with their associated interlocks. The various switching sequences are effected solely by mechanical means so that the amount of small wiring is reduced to a minimum.

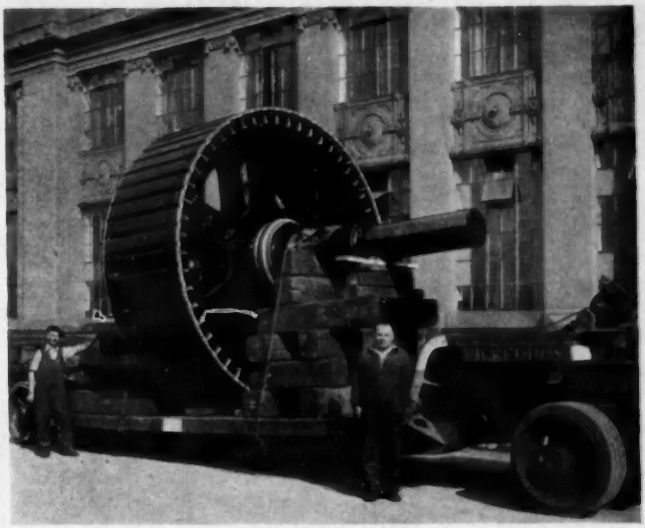


Fig. 17.—Magnet wheel of a 6,800 s.h.p. synchronous ship propulsion motor in course of transport.

Most of the electrical equipment for five other large cargo ships has also been manufactured. The equipment for one of these ships, which is typical, comprised three 300 kW generators and one of 150 kW, main switchboard, plural starter switchboard and motors for engine room auxiliaries and steering gear.

Lloyds Register of Shipping has specified the use of high duty fuses where the generating plant exceeds certain capacities. G.E.C. high rupturing capacity fuses have been approved for these duties, and short circuit tests were made on one of the earliest vessels in which they were used. These tests gave valuable information for future use.

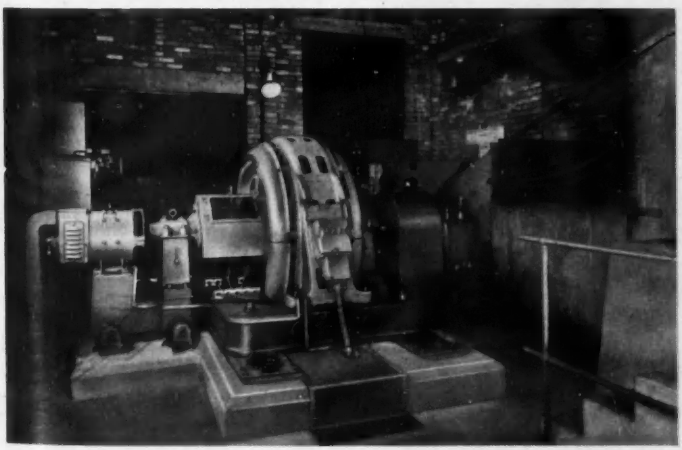


Fig. 16.—A 500 h.p. 3.3 kV salient pole synchronous induction motor driving the main ventilating fan through vee ropes, at the Cefn Coed Colliery, Amalgamated Anthracite Collieries, Ltd., South Wales.

GRAVING DOCK ELECTRIFICATION.

Of several large dock electrification schemes undertaken, brief particulars may be recorded of one at Sydney, for the Government of the Commonwealth of Australia. The dock pump house equipment comprises three 1200 h.p., 5 kV, salient pole synchronous motors driving the main dewatering pumps. There are also a large number of motors driving drainage, fire and seepage pumps, etc., and, in addition, motorised valves in the pump house and adjacent valve pits ranging from 1½ to 230 h.p.

A double bus 150 MVA solenoid operated switchboard controls the incoming supplies and the main pump motors. There is also a central control desk and mimic diagram giving centralised control for the whole of the pump and valve operating sequences by means of Gwynnes' control system. The contract also covers a stand-by power station comprising three 1250 kVA, 5 kV, diesel-driven alternators and auxiliary equipment.

The plant in the various sub-stations includes eight transformers of 500 to 1000 kVA capacity, two 600 kW, 220 volt, D.C. motor-generator sets driven by 5 kV synchronous induction motors for ship supply; two 255 h.p. and one 120 h.p. synchronous induction motor driving compressors. There are six 50 kW, 110 volt, portable lighting sets, and six 50 kW, 55 volt, portable welding sets. There is also the complete cable installation for power, telephone, fire and signalling services.

As all the motors, totalling approximately 9,000 h.p., switch, and control gear are below ground level, they are fitted with special heaters to prevent condensation when not in service. The consulting engineers for the whole of this dock are Sir Alexander Gibb and Partners.

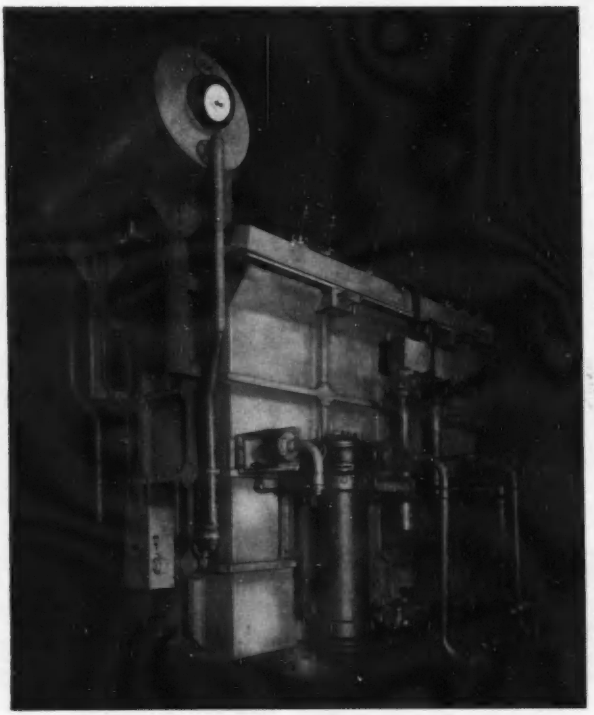


Fig. 18.—A 37,500 kVA 66/22-11 kV 3 phase transformer with water cooled forced oil circulation.

TRANSFORMERS.

Of a great variety of transformers manufactured, mention may be made of one with a B.S. rating of 37,500 kVA for The State Electricity Commission of Victoria, Australia (fig. 18). Cooling is by means of forced oil circulation water cooled (B.S. type O.F.W.). Twin coolers are provided, each capable of dissipating the full load losses of the transformer. This unit is for service on a 66/22-11 kV circuit, the lower voltage windings being arranged for series or parallel connection. The main windings are star/star with a delta connected tertiary winding rated at 10,000 kVA. Tappings are provided on the 66 kV winding by means of an off-circuit tapping switch.

OIL IMMERSED REACTORS.

Three current limiting reactors have been supplied to the Central Electricity Board for use on a 132 kV, 3 phase, 50 cycle system at the Upper Boat Station of the South Wales Power Co. Each reactor is of the single phase oil immersed, naturally cooled type, having a reactance of 18 per cent at a line throughput of 90,000 kVA 3 phase. The rating of each reactor is 5400 kVA.

FRACTIONAL HORSE POWER MACHINES.

Many electrical machines possessing most interesting features have been made in large quantities for various purposes associated with aircraft service (figs. 19, 20 and 21). One of these machines is the camera control motor which has been largely used for driving the mechanism which enables reconnaissance planes to take a series of accurately timed photographs; closely allied is a camera motor for driving the miniature cinema camera which photographs the results of gunfire from a plane. A third type of motor (fig. 20) provides the power for the Mark XIV bomb sight which has been reported as making an outstanding contribution to the smashing of German industry.

A Jack motor (fig. 21) is a small

machine fitted with a brake which operates some of the controls on aircraft, thus relieving the pilot of work. Yet another type of small motor is for varying the pitch of the blades on an

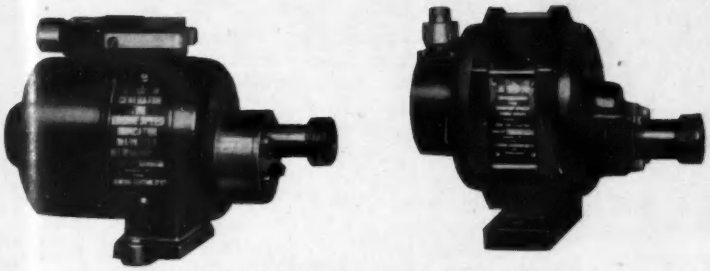


Fig. 19.—D.C. and A.C. engine speed indicator generators.

electrically feathering air screw.

Large numbers of aircraft generators have been manufactured including A.C., D.C. and combined A.C. and D.C. machines, also several types of rotary transformers have been constructed for providing supply for radio purposes on planes.

There has been a great increase in the number of electric fans produced since the war started. Ceiling and table fans have been provided for all the main fighting services and the Merchant Navy; also there has been a great demand for ship ventilating fans for naval service. Motors for driving centrifugal fans for handling air at 300 degs. C. have been designed and made.

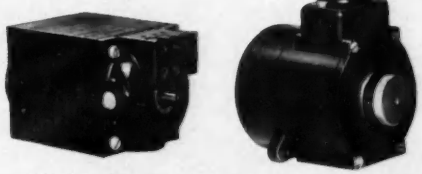


Fig. 20.—Bomb sight driving motor and repeater.

ELECTRICAL DYNAMIC BALANCING MACHINES.

A number of electrically operated dynamic balancing machines have been designed and made in the Witton Development Laboratory for use in the Works (fig. 22). They have been found in practice to give a more accurate and reliable balance than that obtained previously, and in addition are effecting an appreciable saving of time as compared with older methods. The first machine was designed for small armatures, but three subsequent models have been developed in which the range has been extended in both directions; the biggest machine so far made deals with armatures weighing up to one hundredweight.

The armatures to be balanced are run at any speed in spring mounted bearings, the consequent movement of which—due to unbalance—is caused to generate voltages, and after suitable mixing and amplification a reading is given on a meter. The latter indicates the balance weight required at either balancing plane, decided by the setting of a changeover switch. The peripheral position for the balance weight is also indicated from the voltage generated by the vibration. The phase of the generated voltage depends upon the position of the unbalance on the armature, and the amplified and mixed output is used to illuminate the armature stroboscopically by means of a neon-filled discharge tube. The revolving armature is thus seen in an apparently stationary position which bears a definite relationship to the point of unbalance, hence indicating where the balance weight should be attached. By means of variable gain on the amplifier any desired sensitivity can be obtained.

Balance to ·001 oz. is accomplished commercially on one of these machines.

CATHODE RAY ARMATURE TESTER.

Another development has been a cathode ray tester for the production testing of the windings of small armatures (fig. 23a). This machine has been in constant use for some time and about 20,000 armatures have been tested in it so far.

The machine measures the impedance to high frequency current of each coil in the

Fig. 21.—Aircraft Jack Motor.

Fig. 22.—Electrically operated dynamic balancing machine.

armature. These impedances all appear simultaneously as a series of vertical lines on the screen of a cathode ray tube, the length of each line representing the impedance of one coil of the armature. Any fault in the coil alters its impedance and therefore the length of the corresponding line (fig. 23b). By the movement of a handle the faulty coil can be simply located on the stationary armature at the end of the test.

The armature is revolved at any speed during the test and the supply and impedance voltages are connected to, and measured from, the armature by means of brushes on the commutator.

Compared with the normal test methods the machine has the following advantages: testing time is reduced to about one tenth; faults are much less likely to be overlooked; the windings can be subjected to full centrifugal force; voltage can be normal; and the condition of the commutator surface is included in the test.

IRON ORE.

During the period that the sources from which iron ore is normally obtained have not been available, the development of iron ore deposits within the Empire has become a matter of primary importance.

The complete mechanical and electrical equipment for a very large iron ore concentrating plant has been installed and put into operation in West Africa. It is hoped to describe this installation at a future date in this Journal.

PYRITES PLANT.

A plant for the recovery of pyrites (FeS_2) from the shale rejects of the coal cleaning equipment has recently been supplied to Horden Collieries. The cleaned pyrites forms the source of sulphur in the manufacture of sulphuric acid.

The pyrites is separated from the shale in the Recovery Plant, and in the process clean coal is also recovered. The apparatus supplied comprises the entire mechanical and electrical equipment necessary.

SHERWEN VIBRATING TABLE.

The principle of the Sherwen vibrating table has been applied to the consolidation of concrete, resulting in exceptional strength in the concrete and in notable saving in time. Being electromagnetically operated all rotating machinery is dispensed with, and wear and maintenance are reduced to a minimum (fig. 24).

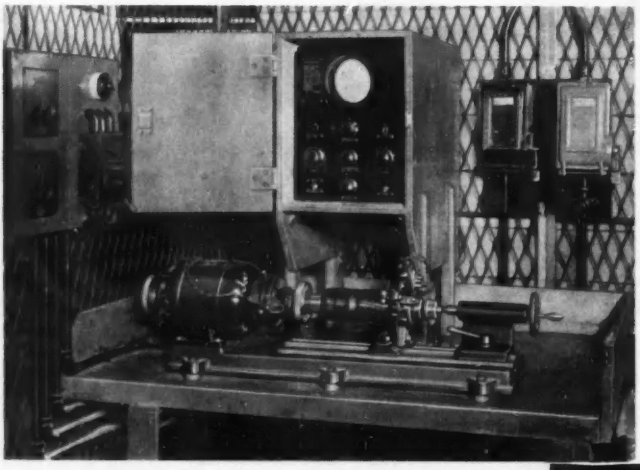


Fig. 23a.—(left) Cathode ray armature testing apparatus.

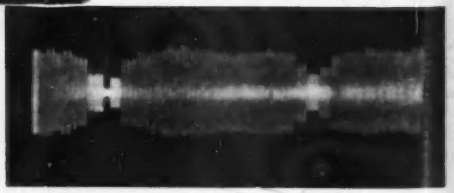


Fig. 23b.—(below) Record from a faulty armature with one earthed coil.

An interesting application of the Sherwen vibrating table has been in the separation of bent from straight radio valve pins. The table is electro-magnetically vibrated and is capable of removing all pins with a bend exceeding 0·006 ins. or a lip of more than 0·003 ins. A bent pin fed to the press machine may hold up production of glass valve bases for 10 to 15 minutes. Pre-sorting has entirely eliminated the trouble.

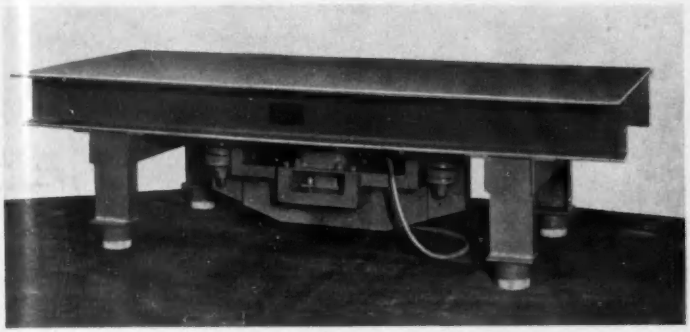


Fig. 24.—Sherwen vibrating table for the consolidation of concrete.

MINERAL PROSPECTING.

A convenient portable unit for prospecting purposes makes use of the property of certain minerals in fluorescing under short-wave ultra-violet radiation (fig. 25). The unit comprises a cold cathode mercury vapour discharge tube associated with a converter to supply the required A.C. from a low voltage D.C. supply, such as a 12 volt car battery. Designed primarily for the rapid detection of scheelite, the apparatus can be readily used with other materials including some radium bearing uranium ores and certain oil bearing sands.

ELECTRIC LIFTS.

In addition to work of a highly specialised character for the Services, the Express Lift Co., Ltd., has fulfilled a certain number of contracts for goods lifts for armament and aircraft factories, power stations, hospitals and similar institutions.

Such development work as has been possible has been directed towards the standardisation of complete lift installations as distinct from components. In spite of the obvious difficulties of the subject, a high degree of success has been attained, the results of which should prove far-reaching in post-war days.

OSRAM FLUORESCENT LAMPS.

The Osram 5 ft. 80 W. fluorescent lamp, marketed first in April, 1940, has increased steadily in popularity and its successful and widespread use throughout the war years foreshadows a great future for this form of lighting.

War time restrictions have prevented more than the one size of this lamp from being marketed.

Fluorescent tubes of the cold cathode type working on high voltages have been known for some years, but the 5 ft. 80 watt lamp operates on mains voltages from 200 to 260 volts. Its rated efficiency is 35 lumens per watt, this high efficiency being largely due to the discovery in the Research Laboratories of zinc beryllium silicate, one of the chief constituents of the mixture of fluorescent powders with which the lamp is coated.

Until recently, only the daylight colour has been generally available, but a warm white colour was marketed at the beginning of the year. The new colour gives a most pleasing effect and should have many applications in offices, shops, restaurants and cinemas as well as in factories.

Fig. 25.—Portable prospecting outfit.

Experimental work is also being done on the development of clear, low-pressure mercury tubes capable of emitting ultra-violet radiation for killing airborne bacteria. They may have important applications for industrial and commercial purposes.

Fig. 26.—250 watt Osira box-type compact source lamp.

Fig. 27.—Gunsight lamp for the accurate aiming of aircraft guns.

HIGH-PRESSURE ELECTRIC DISCHARGE LAMPS.

Considerable work has been done on the development of high intensity high-pressure mercury vapour lamps of both the water cooled linear source and the air cooled compact source types. In the water cooled linear source type the mercury vapour is operated at pressures up to 100 atmospheres, and the arc (formed in a narrow capillary) has a brightness of some 30,000 candles per sq. cm. The arc in the compact source lamps is approximately square in shape, both dimensions being a few millimetres; the arc brightness in the larger lamps exceeds that of the high current density carbon arc.

The compact source type lamp has been very intensively developed and lamps of high wattage have been made experimentally with success. Lamps of lower wattage rating have been used for a number of applications. At fig. 26 is shown the 250 watt box type compact source lamp which has a light source only 3·5 mm. long and a brightness of 20,000 candles per sq. cm. The metal box serves the double purpose of screening the eyes from the ultra-violet radiation emitted by the discharge through the quartz bulb enclosing it, and to protect the quartz bulb from accidental breakage.

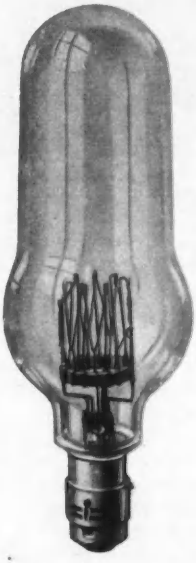


Fig. 28.—Masthead lamp for long distance signalling.

The major application of compact source lamps is in projection work. Considerable quantities of 250 and 500 watt compact source lamps have been made for various optical projection devices used in war time. Associated electrical circuits have also been investigated and lamps can now be brought up to full brightness quickly and restarted when hot without delay. One system which is of considerable interest makes use of a "simmering" circuit by which the lamp can "simmer" at a low wattage and be brought up to full wattage in a few seconds. Moreover, problems connected with the use of forced air cooling have also been dealt with and considerable experience thereby gained. All these developments should be of great value when attention can be given to the use of these lamps for cinema projection.

Fig. 29.—10 kW aerodrome floodlighting lamp.

For certain Service purposes, lamps of the water cooled variety have been produced and production experience gained, which should be useful in the post war period when the possibilities of these lamps can be more fully developed.

FILAMENT LAMPS.

One of the most important filament lamps now being made is the Gunsight lamp used in aircraft (fig. 27). For a long time it was considered impossible to construct a filament capable of withstanding, for more than a few seconds, the intense vibration set up by machine guns or cannon in firing, but the problem was solved in conjunction with the Royal Aircraft Establishment. This lamp has two filaments, one operating at a high intensity for daylight firing and the other giving only a dim glow for use at night.

No less important are the many types of signalling lamps now in use. One of these is the 3 kW Masthead Signalling Lamp, fig. 28, which is specially designed to give the same light output over 360° azimuth and is particularly used by ships in convoy.

Fig. 29 shows a 10 kW aerodrome flood-lighting lamp.

STANDARDS OF LIGHTING.

The effect of the blacking out of large areas of factory windows, and the greater prevalence of night shift work has led to far greater appreciation of the benefit of good artificial lighting. The natural development in this direction has been reinforced by the introduction of Statutory Orders by the Ministry of Labour, laying down minimum illumination of 6 f.c. for all working areas "without prejudice to the provision of any additional illumination required to render the lighting sufficient and suitable for the nature of the work." Interpreting this, the main Service Departments have called for I.E.S. Code Illumination values in all factories under their control.

The full benefit of this trend has been confined to those factories making a major contribution to the war effort, and there still remain very many industrial establishments which have been unable to obtain the necessary supplies of the best lighting equipment during the war.

Greater recognition of the psychological value of good lighting has led to an understanding of the importance of adequate background light, and the introduction of light and attractive colouring to all fixed gear, machine bases, etc.

EQUIPMENT FOR USE WITH FLUORESCENT LAMPS.

The outstanding developments in lighting equipment are related to the 5 ft. fluorescent

Fig. 30.—High intensity local lighting provided by Osram fluorescent lamps. Light escaping from a slot in the top of the reflector provides adequate illumination on walls and ceilings.

tubular lamp, which by its qualities of low brightness, large luminous area and excellent colour rendering has proved the best source yet conceived for almost all forms of general lighting. The range of reflectors designed for use with these lamps includes a white enamel trough reflector which, when mounted at heights of 10 ft. and upwards from floor level, has similar general light distribution characteristics to the standard dispersive reflectors associated with tungsten lamps, and which, mounted at lower heights immediately above the work benches, has led to a new technique sometimes described as "Localised Lighting." This method, a cross between general and local lighting, ensures first-class, relatively shadowless illumination over the important working area with sufficient spread to give some general lighting. Provided the lines of benches are not too far apart, it complies with the statutory requirements of a minimum illumination of 6 f.c. over all working areas. An alternative reflector has a slot in the top immediately above the lamp so as to permit some illumination to reach the ceiling and upper parts of the wall (fig. 30).

A range of mirror glass reflectors to punch the light downwards for the illumination of limited areas from relatively great mounting heights, or to punch it at an angle on to vertical surfaces, has also been developed. Other fittings include plain channels permitting lamps to be mounted unshielded on flat ceilings; similar channels with opal glass panels are used where ceilings are so low that bare lamps would cause glare. Practical experience with these lamps has shown that where high illumination values of general lighting are required, continuous lines of light provide a more pleasing result than scattered units. Therefore reflectors have been designed for mounting as continuous troughs arranged for adjustable suspension from any convenient fixing positions (figs. 31 and 32).

Fig. 31.—The relatively shadowless light provided by Osram fluorescent lamps used for the illumination of layout reproduction processes in an aircraft factory.

For use in inflammable and explosive atmospheres a flameproof 5 ft. trough has been introduced comprising a toughened glass tubular surround to the lamp, fitting into flameproof end-enclosures.

For the lighting of hospital operating theatre tables there has been produced a unit comprising five 5 ft. lamps mounted in a reflector of anodised aluminium troughs.

TWIN TUBE CIRCUIT.

Owing to the slight afterglow of fluorescent powders the stroboscopic effect with these lamps is never so great as with electric discharge lamps of the high pressure mercury type. However, to reduce it to a minimum, the "Twin Tube" circuit has been introduced. In this circuit alternate lamps are arranged with a condenser in series with the choke, giving alternatively capacitatively and inductively operated circuits. The result is equivalent to running alternate lamps on two separate phases of a three phase supply. A further advantage of this circuit is that unity power factor is achieved.

Much work has been done to determine the best method of using these lamps and to prepare data for the use of lighting engineers in computing illumination results. In co-operation with other manufacturers, investigations have been made with the object of standardising a technique of rating illumination, and also to study the reduction of shadow.

High pressure mercury vapour lamps have continued to find many applications in industry, particularly in very lofty buildings, such as shipyards, foundries, steel works, etc., where the conditions of installation and the fact that only relatively low wattage lamps are available, have made the use of 5 ft. lamps impracticable, or where the nature of the work has not justified it. A special reflector combining tungsten and high pressure mercury lamps in a single fitting has also been used with excellent results.

WARTIME ILLUMINATION PROBLEMS.

Since the early days of the war, the Laboratories have been engaged on a number of problems of visibility, such as the investigation of the visibility of the ground from the air, visibility in searchlight beams and with flares, etc., for various Service and other Government Departments. At an early stage it became apparent that these problems could not be solved without data on the photometric properties of the upper atmosphere, which were not available.

The Laboratories therefore initiated, through Sub-Committee G (Photometric properties of the Atmosphere) of the Civil Defence Research Committee, Ministry of Home Security, a programme of research on the properties of the atmosphere. A new instrument was devised and constructed capable of measuring the light scattered in various directions by the atmosphere; and through the co-operation of many other laboratories and Service establishments this and other apparatus was flown to heights up to 30,000 ft. on a number of occasions. A series of very interesting curves was obtained, which may be found to be of considerable theoretical interest. Other measurements which enabled the results to be checked were taken on some flights, such as the transmission from air to ground, obtained by measuring the brightness of a white sheet only 40 ft. square from altitudes up to 18,000 ft.; and the brightness of the beam of a vertical searchlight.

It was also desired to investigate the properties of industrial haze, which differs from clean air in that it contains absorbing smoke particles in addition to scattering particles. In a further series of experiments the apparatus was taken on an observation balloon and the scatter was measured in an industrial neighbourhood; simultaneously the air-ground transmission was measured carefully by observing the brightness of an illuminated white sheet. From these measurements, if taken with sufficient care, it is possible to determine the absorption as well as the scatter of the atmosphere at each altitude.

Further series of measurements with the Laboratories' apparatus have been made, some by Service establishments at ground level.

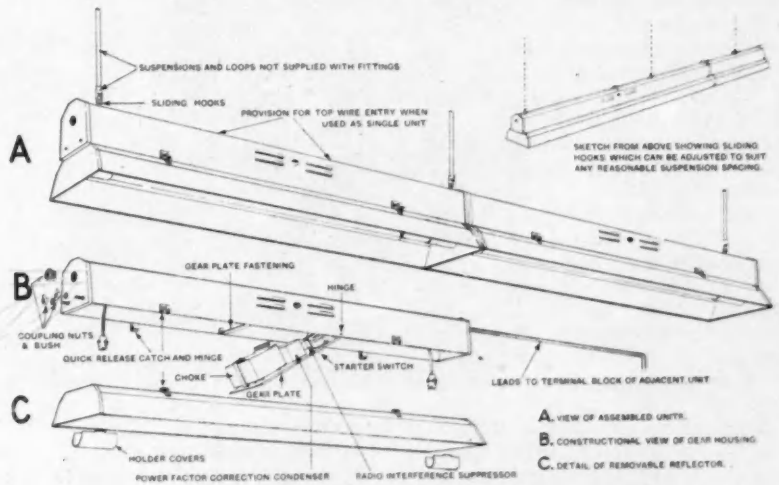

SUSPENSIONS AND LOOPS NOT SUPPLIED WITH FITTINGS
SLIDING HOOKS
PROVISION FOR TOP WIRE ENTRY WHEN USED AS SINGLE UNIT
A
SKETCH FROM ABOVE SHOWING SLIDING HOOKS WHICH CAN BE ADJUSTED TO SUIT ANY REASONABLE SUSPENSION SPACING.
GEAR PLATE FASTENING
HINGE
B
COUPLING NUTS & BUSH
QUICK RELEASE CATCH AND HINGE
STARTER SWITCH
LEADS TO TERMINAL BLOCK OF ADJACENT UNIT
CHOKE
GEAR PLATE
C
HOLDER COVERS
POWER FACTOR CORRECTION CONDENSER
RADIO INTERFERENCE SUPPRESSOR
A. VIEW OF ASSEMBLED UNITS.
B. CONSTRUCTIONAL VIEW OF GEAR HOUSING.
C. DETAIL OF REMOVABLE REFLECTOR.

Fig. 32.—Diagrammatic view of continuous trough for use with 5 ft. Osram fluorescent lamp.

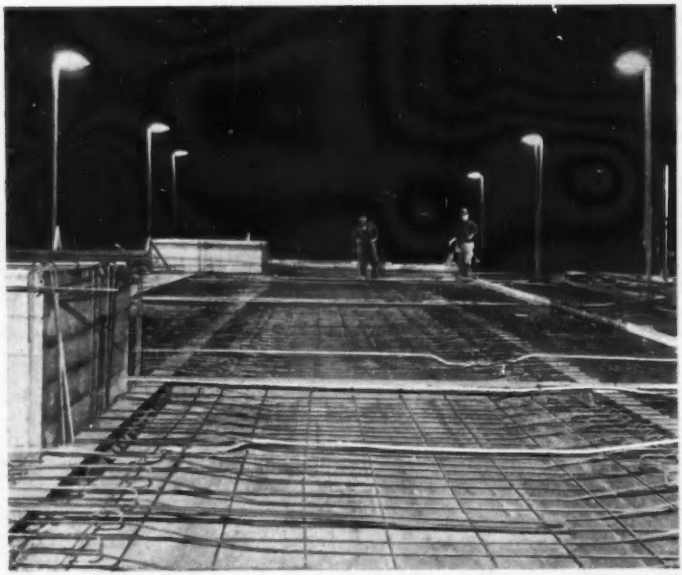
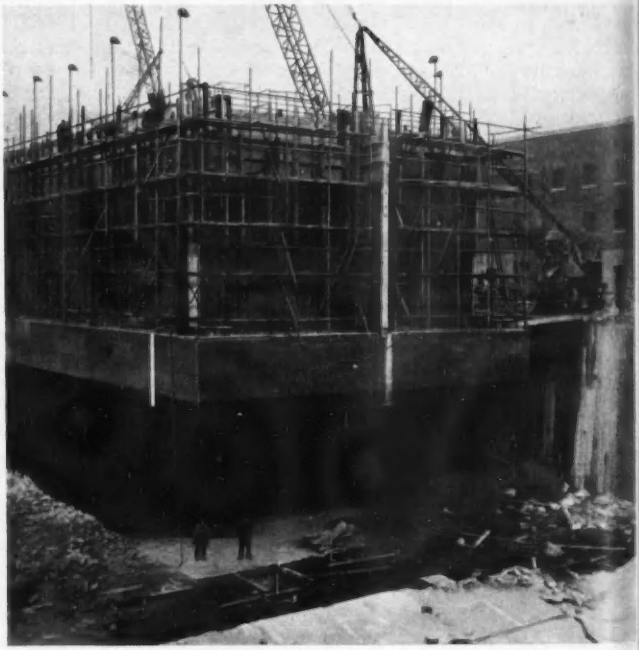


Fig. 33 (left).—Roof shuttering under an illumination of 0.2 f.c. Experimental lighting to determine illumination standards for night work under blackout conditions.

Fig. 34 (below).—Construction of the Mulberry Harbour, which was taken to France on D-day. The fittings designed as a result of the experiments shown in fig. 33 were extensively used during constructional work.



From this work data have been obtained which have enabled many visibility and similar problems to be solved which could not have been attempted without it, and laboratory techniques have been established whereby many such problems can be solved quickly with a minimum of field or full scale experiment.

Members of the staff of the Research Laboratories also have served on, and carried out much experimental work on behalf of, other B.S.I. Committees dealing with A.R.P. lighting, including those dealing with fittings for various low illumination signs and luminescent materials.

In this connection, a range of reflectors has been designed to comply with Specifications B.S. A.R.P. Nos. 16, 20 and 21 dealing with lighting of outside areas of industrial premises, also fittings to comply with A.R.P. specifications for window lighting and window signs.

Fittings designed for special A.R.P. problems include battery operated portable floodlights for use by First Aid parties, etc., and easily portable single- and multi-lamp reflectors for temporary First Aid stations and similar places. For use in advanced field dressing stations a highly efficient light-weight operating theatre fitting has been produced

employing a spun anodised aluminium reflector. This fitting is easily portable and gives shadowless light.

In co-operation with the Ministry of Supply a very interesting investigation was carried out to determine methods of lighting and minimum practical illumination standards for out-door constructional work at night. As a result, all types of building processes, as well as excavation work, have proceeded safely under blackout conditions. One special fitting used was designed to project a relatively even light of 0·2 f.c. over a given area from a position at one side (figs. 33 and 34).

Similar investigations were undertaken in

Fig. 35.—Lamp standard still holding firm despite damage by blast.

conjunction with the Admiralty and Ministry of Home Security regarding the illumination of shipyards for night work; fittings were also designed to assist in navigation. Much information of permanent value was acquired in the course of these studies.

STREET LIGHTING.

New designs of street lighting lanterns which were in hand at the time of the outbreak of war will be ready to go into full scale production as soon as conditions permit. The fact that exterior lighting equipment has not received the normal amount of maintenance during the war has constituted a useful testing time for lanterns, discharge lamp auxiliaries, brackets and supporting poles. The lessons to be learnt from detailed examination of these items will be helpful in future designs. Generally, the equipment has satisfactorily

Fig. 36.—G.E.C. Uniway lantern.

withstood this form of deterioration as well as the effects of air raids* as will be seen from the illustration, fig. 35. From every point of view it is certain that an immense amount of study will be necessary in regard to post-war exterior lighting.‡ Fig. 36 illustrates the Uniway lantern, a typical design of lamp indicative of future trends in arterial road lighting.

Besides the study of lantern and equipment design, the question of suitable street lighting layouts for arterial road lighting, roundabouts, tunnels, etc. has been investigated jointly with the Research Laboratories, which will enable the Company to contribute to the finalising of the Street Lighting Specification of the British Standards Institution which was incomplete at the outbreak of war and is being re-drafted to cover the recommendations of the Ministry of Transport Street Lighting Final Report, 1937, suitably modified to take account of the latest technique and street lighting practice.

AERODROME LIGHTING.†

During the war a very large amount of aerodrome lighting equipment has been manu-

* Osram Bulletin, Vol. XXI., No. 2, October, 1943. "The Reconditioning of Street Lighting Installations," by H. H. Ballin.

‡ Public Lighting, Vol. IX., No. 35, October-December, 1944. "Street Lantern Design," p. 103.

† "Lighting of the Portela Airport, Lisbon," in this issue of the G.E.C. Journal, p. 152.

factured and supplied, including airfield runway lighting and mobile equipments comprising floodlights, lighthouses and beacons (fig. 37). Detailed improvements in technical and optical design have been effected, while modifications in construction have made possible economy in man power which has been necessary under war-time conditions in order to obtain maximum production. Other apparatus for training, signalling, indication and control has also been supplied.

MARINE LIGHTING.

Special lighting arrangements have been necessary on merchant ships due to blackout conditions; totally enclosed fittings have been provided for the chartroom free from white light leakage and with a special orange tinted filter glass at the bottom. This orange light, while not interfering with the true reading of coloured markings of charts, gives a quicker adaptation of vision when passing from the lighted chartroom to the outer darkness and vice versa.

Lighting devices take a prominent place amongst life saving appliances on merchant ships. A buoyant electric light must be attached to rafts and buoys to indicate the presence of survivors. It is stowed in an inverted position and lights automatically when floating. It is attached to the buoy or raft by a life line.

The G.E.C. Life-Light is fitted with a simple gravity switch operating on the Archimedean screw principle which prevents the light flashing due to shock or pitching when stowed on an upper deck and thereby betraying the ship's position.

A jacket life-light must be carried by every merchant seaman. It can be easily switched on by him should he have to jump into the water. The light is a red one to distinguish it from rafts or buoys and therefore rescue parties will attend first to the red lights, and men in the water will swim towards a raft which carries a white light and not towards another man wearing a red light. The G.E.C. Jacket Life-Light is attached to the wearer by a short lanyard and can be waved at arm's length, but otherwise will float.

A modified form of the G.E.C. Jacket Life-Light has been used exclusively by the R.A.F., special pockets for it are made in the Mae West.

GLASS MAKING AT 2000°C.

Glass is usually melted at temperatures between 1,350° and 1,500° C., but new types of glass which have recently been developed to fill particular needs require melting temperatures as high as 2,000°C. As few refractory materials will withstand this temperature, small molybdenum crucibles which were heated in a specially designed electric resistance furnace were used as containers for the glass during the initial development stages. The glass made in this way was dark in

Fig. 37.—Aerodrome mobile beacon.

colour and prone to crack when used in the factories and these defects proved to be due to the presence of minute particles of molybdenum in the glass and an alternative container had to be found. A small tank furnace of about 2 sq. ft. melting area was therefore constructed which was capable of operation at 2000°C.; it was lined with a zircon refractory produced in the Research Laboratories and was heated by a water cooled oxy-coal gas burner. Additional heat was supplied by passing a current of electricity through the molten glass using tungsten rods as electrodes. The glass scarcely conducts electricity until its temperature exceeds 1800°C., but by the time its

temperature has reached 2000°C. several kilowatts of energy can be dissipated. The glass prepared in this manner exhibited neither of the defects of the earlier samples; it was of good colour and showed no tendency to crack. The glass is drawn into rod form through an iridium die in the bottom of the tank; iridium being practically the only metal which can be used under these conditions. A fuller description of the process has been given in the Journal of the Society of Glass Technology, 1944, Volume 28, pp. 105-112.

X-RAY GLASS.

In melting glasses of rather unusual composition, careful selection of the material for the container is often necessary, and it has been the practice in the Osram G.E.C. Glass Works for the past six years to use platinum crucibles when necessary for this purpose. A case in point is that of glass transparent to X-rays which is finding increasing use in industry. It is melted in a fairly large platinum pot and is supplied in the forms of rod and tubing.

GLASS TUBING.

The installation of a fairly extensive glass tube drawing plant in the years before the war has proved its value on many occasions, particularly when calls came for urgent war work. Tubing of special sizes, or in special forms, has been produced for such varying purposes as land-mines, containers for Penicillin, the storing of blood for transfusion, the ignition of grenades and many other uses. A most vital need has been met in the manufacture of ampoules used for medical and surgical purposes which require a very special glass manufactured solely by the G.E.C.

LUMINESCENCE.

Much of the work on luminescent powders has been directly on war-time problems, such as cathode ray tube applications. Important progress has been made in conjunction with Messrs. Lumifax, in the improvement of existing luminescent powders, and in the development of entirely new types.

Typical of the special problems which have arisen may be mentioned the development and production at the Research Laboratories of deck landing bats for the Admiralty employing a special fluorescent-material, and investigations into the detection of minute cracks in metals, particularly tungsten wires, by means of fluorescence.

RADIO COMMUNICATION.

In addition to the great amount of work undertaken for the fighting services, investigations have continued on the design of equipment for point-to-point communication in the region of wave lengths of one to ten metres. Many field trials have been made to determine whether modulation of the frequency of a radiated carrier wave offers a more effective method of transmitting speech than modulation of amplitude as formerly. Results have proved conclusively that with optimum conditions of modulation, the new system is greatly superior. For example, while amplitude modulated signals to police cars in dense traffic tend to be masked by interference from car ignition systems, frequency modulated signals are substantially free from interference. The most recent equipment therefore embodies this type of modulation.

Another subject which has received attention is the stabilisation of the frequency of transmitters and receivers to give satisfactory results without the use of a large number of accurately cut quartz crystals.

The demand for sound reproduction equipment of all kinds has increased very greatly. Installations for "Music While You Work" have become extremely complex due to their having also to fulfil the A.R.P. and general administration requirements of a factory. Aerodrome installations have involved much investigation into the relative efficiency of different wiring methods. For these applications a range of high power amplifiers has been developed; the total output in some cases has been as high as 12 kW.

QUARTZ OSCILLATOR CRYSTALS.

Quartz crystals for stabilising the frequency of oscillators deteriorate with time. This ageing process, which is due to surface changes occurring after manufacture, has been overcome by a new production process. A principle for evaluating the performance of such crystals has been evolved together with the necessary measuring equipment. Both these developments are being followed on an inter-Service basis.

New methods of mounting crystals by soldering wires to their metallised surfaces have enabled very satisfactory performance to be achieved.

Various X-ray diffraction methods of determining the direction of the principal axes in crystals of quartz have been investigated.

High accuracy of orientation in the quartz plates used for telecommunication pur-

poses is required, and since much of the raw material consists of rough crystals without natural facets, classical crystallographic means cannot be applied. The first method developed for factory use was based on the X-ray rotating crystal principle, and utilised a simple piece of apparatus with a moving crystal. Later, X-ray ionisation and spectrometer and Laue photographic methods were considered. An ionisation spectrometer method was finally adopted for a large proportion of the control work.

TRANSMITTING VALVES.

The development of transmitting valves has been almost entirely directed towards production for use above 200 Mc., formerly regarded as very high frequency. One outcome has been the "micropup" series of valves typified by ACT. 19. Advantages of this form of construction are briefly :—

(*a*) the elimination of the glass envelope and the use of an external anode, rendering possible high dissipation with minimum size.

(*b*) internal valve leads arranged to form part of the concentric lines which must be used as tuning elements.

(*c*) the ample cathode area can be used to give the high emission needed for pulse operation.

An interesting development in the highest power range of transmitting valves is the use of forced air cooling for types previously water cooled. While water cooling is still preferred for most permanent installations, there are many applications where it is impracticable. In such situations the valve is air cooled by a special radiator and an electrically driven blower.

RECEIVING VALVES.

As in the case of transmitting valves, the development of receiving valves has been confined to Service requirements. Considerable progress has been made in the design of valves for very high frequencies, in many cases involving completely new technique in construction. The high cathode current necessary in high frequency triodes and cathode ray tubes has been achieved by improvements in the performance of oxide-coated cathodes, and much fundamental research in this field has borne fruitful results. Fundamental research is also being done on secondary emission.

Special valves produced for war purposes include several types of all glass construction eliminating the need for a top grid connection in screened valves and resulting in better chassis layout. The short leads ensure more efficient high frequency operation.

The demands of war have stimulated work on high voltage thermionic rectifiers of quite small dimensions, some of which are adaptable to television use. Outputs up to 5 kVA can be obtained from valves comparable in size with the average receiving valve. To meet Government demands a range of "miniature" receiving valves has been introduced which have proved very popular in Service equipment ; they are likely to prove equally so for peace time radio where small size is important.

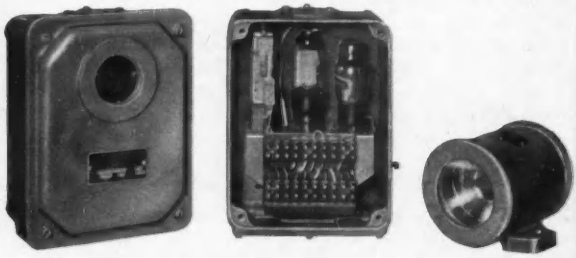


Fig. 38.—New A.C. mains photo-cell relay amplifier and projector lamp house.

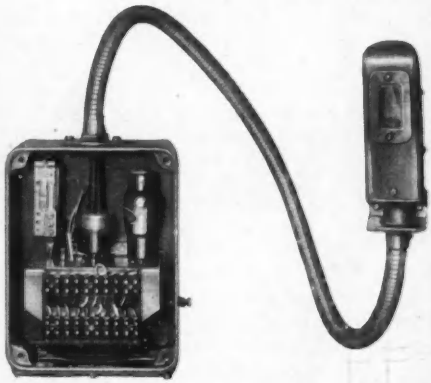


Fig. 39.—Amplifier with photo-cell extension unit in position.

PHOTO-ELECTRIC AMPLIFIER.

An improved form of photo-electric amplifier operates through a transformer incorporated in this unit from a 200/250 volt 50 cycle A.C. supply, and embodies a photo-electric cell and a single stage amplifier actuating a relay (fig. 38). Mains resistances have been eliminated thus removing the source of internal heating which was a disadvantage in earlier

types. The terminal panel is provided with an anode link so that the valve emission may be easily measured by inserting a milliameter.

The transformer has a 12 volt winding to supply the lamp which is required for most applications. The sensitivity of the set is adjustable by the use of alternative voltage tappings for the photo-cell, and spare terminals are provided for an additional set of contacts which can be accommodated on the relay.

For use with the amplifier a compact lamphouse is available comprising a cast iron housing for the optical system and a 12 volt 12 watt horizontally mounted lamp. The front of the case can be fitted with an infra-red screen where operation by invisible radiation is desired.

The amplifier unit is suitable for controlling loads up to about 50 watts without the addition of any switchgear, but beyond this an intermediate contactor can be provided.

When considerations of space necessitate the separation of the photo-cell from the amplifier an extension unit may be used (fig. 39). This is plugged into the 4-pin holder on the amplifier chassis, the leads being taken through a screened flexible tubing up to a distance of 3 ft.

CATHODE RAY TUBES.

Four standard size of high vacuum cathode ray tubes are now commercially available the screen diameters of which are respectively 4 cms., 7 cms., 9 cms. and 16 cms. These all have green willemite screens and show considerable improvements in brightness and focus over the types hitherto available. Fig. 40 illustrates a miniature cathode ray tube, screen diameter 1½ ins.

EMERGENCY TELEPHONE EXCHANGES.

To meet the possibility of the destruction of telephone exchanges by enemy action, the British Post Office has evolved a system of emergency semi-automatic exchanges which can be installed within a very short time to provide essential telephone communication until the permanent equipment can be replaced. In operation a caller is connected via a linefinder or preselector to a manual board, where the operator dials the desired number through the automatic exchange equipment.

Four 4,000-line semi-automatic exchanges with 2,000-type equipments have been designed in conjunction with the B.P.O., three with 200-point linefinders and the other with preselector equipment, and at least one of these was used when a South Coast town exchange was destroyed in 1940. Each 4,000-line equipment can if necessary be split into two complete 2,000-line exchanges.

All equipment is designed for the speediest possible installation. On the automatic equipment racks the shelf-jacks are cabled to terminal strips at the top of the racks. The intermediate distribution frame units are pre-jumpered to give through connections as soon as the rack cables are connected, this jumpering to be changed after the exchange is in operation to suit the traffic conditions. Cable racks, overhead ironwork and power distribution equipment are so designed that they can be erected to suit the requirements of the site.

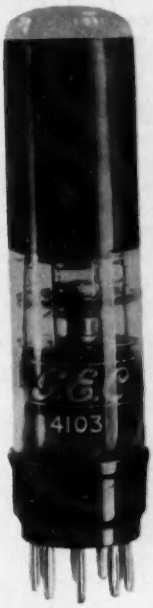


Fig. 40. — Miniature cathode ray tube, type E.4103.B.4. (1½" screen).

The fullest possible tests were made in the factory to reduce testing on the site to a minimum and the equipment is packed in specially designed storage cases to facilitate inspection and reconditioning at frequent intervals.

Two 800-line preselector exchanges have also been supplied. These are intended as satellite exchanges and are provided with discriminating selector equipment. In general the construction is similar to that of the larger exchanges, except that a further saving in installation time is effected by the pre-connected cables on the I.D.F. units. This

enables the switchboard cables to be run directly the I.D.F. units are placed in position.

RAILWAY TRAIN CONTROL.

Two large train control installations have been completed, one for the London, Midland & Scottish Railway Co. at Manchester and the other for the London & North Eastern Railway Co. at Aberdeen, while several long-distance selective ringing telephone systems have been supplied for railway train control in India.

SUPERVISORY CONTROL.

The value of centralised control in large power distribution systems and traction systems by means of supervisory control is now widely appreciated, and apart from smaller equipments, more than a dozen major installations have been completed in Great Britain, Australia, New Zealand, South Africa and South America in the last four years. Of these, three are of particular interest, namely a group of systems on a British rural power distribution network, the Melbourne Suburban Railways system, and the Brisbane City Tramways system.

Details cannot yet be published of the location of the equipment in England but in one particular area five large supervisory control installations give centralised control of more than twenty distribution substations. Voice-frequency signalling is employed on all five systems, for the most part over pilot lines, but on four sections carrier equipment provides communication over the power lines themselves. Inter-tripping facilities are also provided over certain of the carrier links. A comprehensive telephone system serves the whole area, with code-ringing party lines for local calls, and facilities for through calls to more distant stations. At one centre there is a small automatic exchange, and where necessary, dialling is repeated over the carrier links.

The Melbourne Suburban Railways supervisory control system gives centralised control of thirty-eight traction substations. The standard G.E.C. four-wire check-back D.C. signalling circuits are employed and the equipment is divided into ten groups, each a complete supervisory control system in itself. The indicator panels for the D.C. distribution network are set in a semi-circle round the control room, with two separate indicator panels for the high-voltage A.C. power supplies. The control keys are mounted on the engineer's desk in the centre of the room.

The Brisbane City Tramways system is a smaller two-wire D.C. signalling check-back system which has proved so satisfactory in operation that a large extension is already in progress.

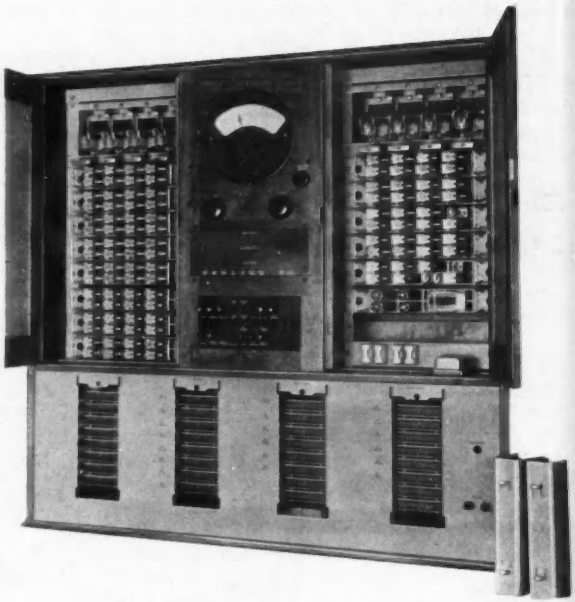


Fig. 41.—Automatic tester for aircraft harness.

Recently a new step-by-step check-back system has been developed and is in operation in one of the latest installations on the British Grid. Its advantages over the older system are enhanced reliability with a possible increased speed of operation and economy of equipment, though as yet it is applicable only to non-tandem systems controlling a single substation.

RIPPLE CONTROL.

During the last four years a number of ripple control systems has been installed in Government factories and depots, in an important dockyard, a harbour installation, and a city in the South of England, and the facilities provided range from automatic time signals to the control of lighting, air raid sirens, imminent danger warnings and fire alarm calls. Abroad, the system has been applied in New Zealand for the automatic

switching on and off of water heaters at specified times, in connection with a three-period tariff scheme.

The ripple control system was originally developed for the centralised control of street lighting and of peak loads on power distribution networks. It dispenses with the need for separate control wires, since all signalling takes place over the conductors of the power network, a ripple frequency being injected into the network at a convenient point to operate sensitive tuned relays located at the remote switching points. A separate ripple frequency may be used for the control of each switching operation, or alternatively by the use of coded signals a single frequency may control several different operations.

AUTOMATIC TESTERS.

A number of automatic testers has been supplied for the testing of aircraft harnesses and junction boxes during manufacture (fig. 41). An interesting development from the telephone exchange routiner, the tester is connected up to the unit to be tested and then proceeds to test the continuity and insulation of each lead with a speed and certainty which cannot be approached by manual testing methods. If a fault is found the tester sounds an alarm, and indicates by means of lamps the faulty lead and the nature of the fault.

Such testers can be designed for a variety of purposes and according to the facilities required may range from small and inexpensive portable units to large permanent installations.

ELECTRIC FURNACES.

A 100 kW continuous roller hearth furnace possessing the unusual feature of a worm gear drive, was recently described in this Journal.* An interesting innovation consists in the use of a photo-electric cell to indicate when a charge is ready for removal.

Three very large double-chamber batch type annealing furnaces have been built for the heat treatment of aluminium sheets.

Another interesting installation consists of a batch of three rotary hearth furnaces for treating glass for moulding optical lenses, and a continuous lehr with mesh belt conveyor 26 ft. long for annealing the lenses.

There has been developed complete electric furnace equipment with atmosphere producing plant for gas carburising, including a cooling chamber to take the charge after carburising.

*G.E.C. Journal, Vol. XII., No. 4, August, 1943. "Electric Furnaces for Heat Treatment of Metals," by Verdon O. Cutts, page 186.

A large number of mesh belt conveyor type furnaces has been built for the heat treatment of steel bullets, the heated bullets falling through a chute into an oil quench tank. An inclined V-trough conveyor facilitates removal of the hardened pieces from the tank. Twenty-three of these furnaces have been supplied to India.

Two large vertical cylindrical furnaces with forced air circulation have been built for the heat treatment of aeroplane propellers. The propellers are suspended and, besides quenching arrangements, quick acting lifting tackle is provided for rapid transference of the charge from furnace to quench. There has also been constructed a very large vertical cylindrical furnace specially designed, with zone control, for the heat treatment of long rolls.

Fig. 42.—Controlled atmosphere plant for use in the bright annealing of high carbon steels.

The 180 kW chain conveyor type continuous billet heating furnace, 20 ft. long by 3 ft. 6 ins. wide by 9 ins. clear working height, previously described in this Journal,* represents a definite advance in this type of equipment. It is used for the heating of widely varying sizes of aluminium alloy billets for forging.

Mention may also be made of a 300 kW continuous furnace for the bright annealing of steel sheets up to 24 ins. wide supplied to

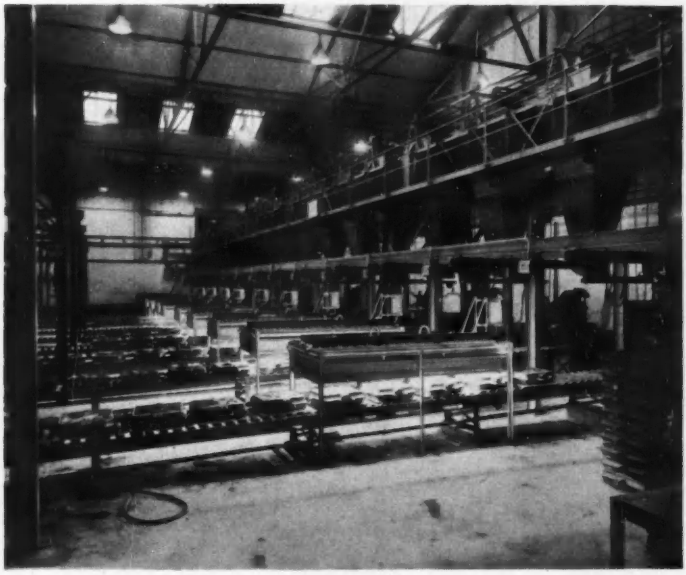


Fig. 43.—Drying moulds in a foundry. The installation comprises 38 units containing 1368 Osram infra-red industrial lamps; total loading 340 kW.

Richard Thomas and Baldwins, Ltd., and installed at their Wilden Works, Stourport. It is of the live driven roller hearth type, provided with heated and water cooled sections, working with an artificial atmosphere and fitted with variable speed drive.

CONTROLLED GAS ATMOSPHERES

As already indicated, atmosphere producing equipment has been developed for various purposes such as gas carburising, the apparatus for which gives rapid and uniform carburising free from sooting or oxidation. A charcoal burner has been developed to produce an atmosphere in which many non-ferrous metals and mild steel strip can be bright annealed; in addition, high carbon steel strip can be bright annealed without danger of decarburisation (fig. 42).

Plant has also been developed for producing an atmosphere in which gas carburising can be carried out more rapidly and uniformly than by the old pack hardening method.

GAS MALLEABLEIZING.

Electric furnaces in conjunction with artificial atmospheres are able to produce white heart malleable iron in very much less time than is possible with older existing processes.

SPACE HEATING.

The most important development in connection with electric space heating is the successful introduction of the Unit heater. These heaters, comprising fans and heater elements fitted with thermostatic control and safety device, are available in five ratings from 2½ to 20 kW. Their principle advantages are flexibility, economy in material, ease and cheapness of installation and even distribution of heat throughout a large space.

If required, the Unit heater can be combined with warm air ventilation by preheating cold air introduced by ventilating fans. Since March, 1940 over 47,500 kW of Unit heaters have been installed in factories engaged on war work.

RADIANT HEATING.

Since the war, radiant heating has become firmly established as a production process. It is employed for paint drying, softening plastics, accelerating the setting of adhesives,

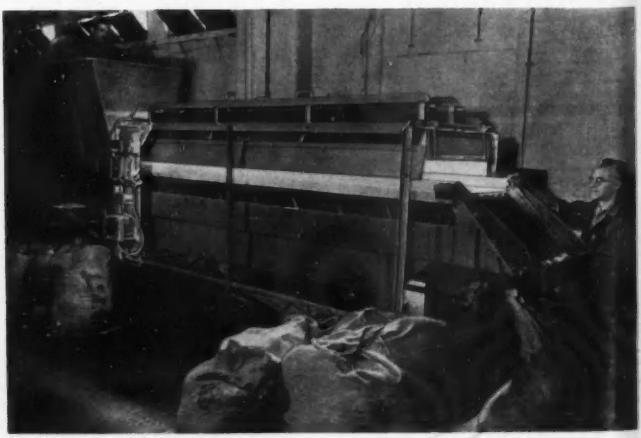


Fig. 44.—Infra-red installation for evaporating moisture from sawdust transported on a vibrating conveyor.

drying foundry moulds, drying impregnating varnish in the coils of electrical apparatus, and a variety of other purposes. In most instances lamps have been used as the source of radiation and, as mentioned below, a number of plants has been made with upwards of 1,000 lamps and loadings exceeding 250 kW. Where more intense radiation is required, exposed nickel chromium heating elements have been employed.

INFRA-RED LAMP HEATING

For this type of heating Osram infra-red industrial lamps housed in trough reflectors are used as source of energy. This is an improvement on the individual round type, the close grouping of the lamps resulting in some cases in an increase in intensity of 44 per cent. In addition, an unbroken reflecting surface is presented to the work, draughts

Fig. 45.—Electric griller for use in aircraft.

between adjacent reflectors are eliminated and disturbing glare is prevented. The reflectors are plated with rhodium, an exceedingly hard metal which is resistant to periodic cleaning.

Two 42 ft. plants with a total loading of 500 kW and incorporating 2,000 infra-red industrial lamps, form an installation for drying paint inside and outside petrol containers simultaneously in 7 minutes. Another installation stoves castings weighing over 2 cwt. in 23 minutes, whereas one hour was needed with convection heating. The castings are rotated and the stresses set up are reduced thus permitting machining to be completed before stoving, thereby avoiding damage to painted surfaces. In this instance the economy in labour and power consumption is 70 per cent, the latter amounting to 4,250 kWh a week.

An installation comprising 38 units totalling 342 kW and containing 1,368 infra-red industrial lamps has been put into operation in a foundry for drying moulds which travel through the plant on conveyors (fig. 43). The moulds are skin dried to a depth of $\frac{1}{16}$ in. in four minutes; labour is economised, fumes eliminated and castings are free from blemishes.

For evaporating moisture from sawdust an installation of an unusual type is employed (fig. 44). The sawdust travels in a continuous stream on a "Sherwen" electromagnetic conveyor beneath a bank of 54 infra-red lamps with a total loading of 135 kW.; 400 lbs. of sawdust are treated in 24 hours and from 10 per cent to 20 per cent of moisture by weight is evaporated. Simultaneously the resin is volatilised and eliminated as a sticking agent; this is of importance since the sawdust is used for polishing rollers and balls for bearings. Previous methods failed to remove the resin with the result that corrosion of balls and rollers occurred with consequent loss in production.

ELECTRIC COOKING EQUIPMENT FOR CIVILIAN AIRCRAFT.

An Aeronautical Department has been formed to co-ordinate the development work being carried out in various sections of the organisation. The installation of specially designed aircraft equipment on a York machine of the type used for long distance travel is of interest in the light of future developments. Hitherto the absence of cooking, ventilating and reasonable water heating facilities has detracted from comfort on long journeys. The galley in the York machine referred to is naturally very small but is well designed and compact, cooking utensils and china being stowed with much ingenuity. A lightweight combined grill boiler unit is used for cooking with which is incorporated a hot

Fig. 46.—Water tank fitted with immersion heater for use in aircraft.

cupboard on which the cooker is usually mounted (fig. 45). The unit is adequate for the preparation of complete meals, one such meal having included a 4 lb. joint of roast lamb.

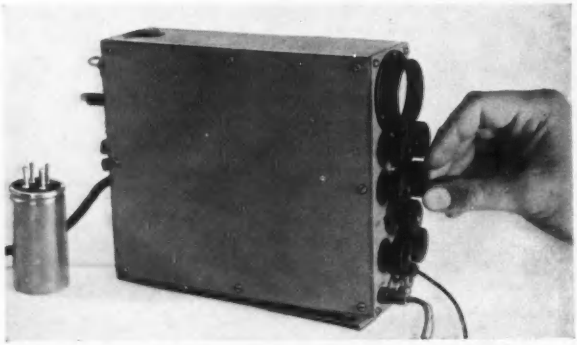


Fig. 47.—The Miniscope: a new miniature oscilloscope.

Hot water is available from two sources; in the galley itself is a two-gallon urn providing hot water for tea, coffee and casual use; larger supplies of hot water are provided by a 12½ gallon tank in the roof of the machine connected to the sink tap (fig. 46). This water is kept hot by a 150 watt thermostatically controlled immersion heater.

In such a small galley efficient ventilation is essential and is secured by the use of an exhaust fan fitted to the side of the machine. This eliminates cooking smells and prevents the atmosphere becoming overheated. Fans are also installed in the lounge and sleeping quarters.

AERONAUTICAL, OPTICAL AND GUN FIRE CONTROL INSTRUMENTS.

As an indication of what has been accomplished under this head, it may be sufficient to list the more important instruments produced for war purposes. These include altimeters, tail drift sights, drift recorders, plan rangefinders, constant speed units, several types of reflector gunsights, prismatic compasses, engine speed indicators, periscope gunsights, tank telescopes, charge regulating switches and predictors, in addition to optical parts of other instruments such as gyro gunsights.

ELECTRICAL INSTRUMENTS.

The existing range of measuring instruments has been improved in performance and new types developed. These include moving coil instruments embodying a new type of instrument rectifier.

In general, metal rectifiers have been produced for a great variety of purposes. The new instrument rectifier is the smallest on the market and enables even a 2 inch rectifier voltmeter to be made completely self-contained both as regards rectifier and resistors. New moving coil and moving iron instruments have been developed of more robust construction and greater sensitivity. The new precision dynamometer sub-standard watt-meter is probably the best in its class at the present time.

ELECTRO-THERMIONIC MEASURING DEVICES.

Production of electro-thermionic measuring instruments has increased enormously and includes apparatus for use from the lowest to the highest frequencies. Every class of instrument is covered such as oscillators, valve voltmeters, signal generators,

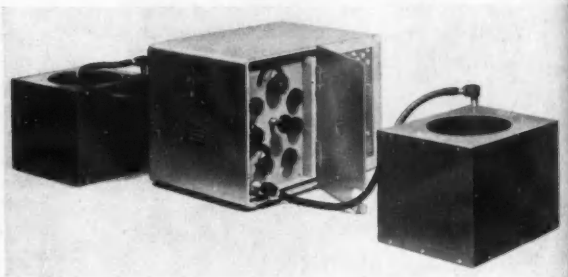


Fig. 48.—Magnetic sorting bridge.

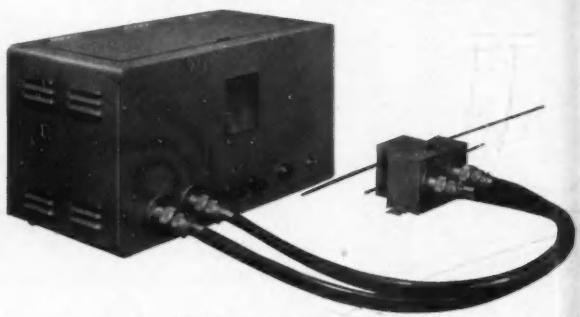


Fig. 49.—Radio-frequency crack detector.

wave meters, etc. To give even a brief description of over three hundred devices is clearly impossible. The valve voltmeter B.W.211 is a typical example. It is a robust, self-contained mains operated instrument with a very large scale and a detachable head unit, enabling measurements to be made at very high frequencies with the minimum influence on the capacitance and inductance of the circuit under test.

Another item of considerable interest is the new miniature oscilloscope, known as the Miniscope and illustrated in fig. 47, which is probably the smallest produced commercially, measuring 8¾ins. by 6⅝ins. by 2¼ins. It is capable of an infinite variety of measurements and is ideally suited for use in servicing all classes of radio receivers and other kindred equipment.

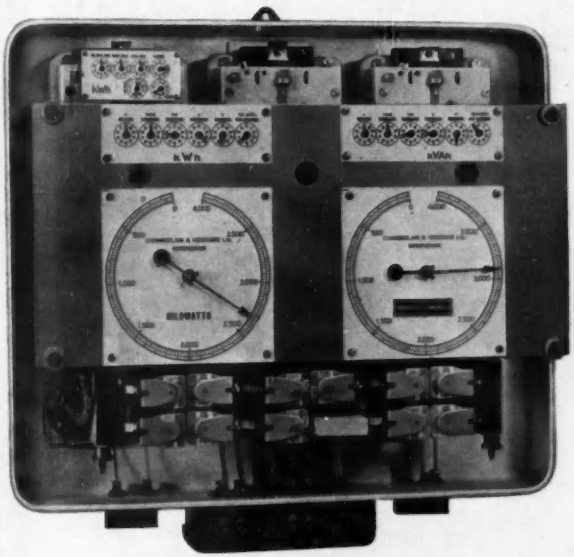


Fig. 50.—Maximum demand meter.

A new department has been established to develop electrical apparatus for measuring the mechanical properties of metals. Two outstanding examples are the magnetic sorting bridge and the radio-frequency crack detector (figs. 48 and 49).

The magnetic sorting bridge permits rapid checking of ferro-magnetic specimens of all kinds, and even enables close approximations to be obtained of the chemical composition and of the hardness. The radio frequency crack detector is designed to detect surface cracks in wires and bar stock and has been used with sizes from 36 S.W.G. to 6ins. diameter. Its action depends on the fact that at high frequencies currents tend to travel on the surface of metals; by suitable choice of frequencies the apparatus can be arranged to measure cracks from ·0005ins. to ·25ins. deep. It may be used with any metal, whereas the magnetic sorting bridge is suitable only for ferro-magnetic materials.

DUST CORES AND QUARTZ CRYSTALS.

The great wartime demand for radio equipment has required the provision of extremely large quantities of dust cores. Previously, much of the iron powder for these came from Germany. The G.E.C., being one of the few firms in non-enemy territory able to manufacture this material and the cores made therefrom, was for a long time the only supplier of these vital components.

Further, the high permeability toroidal dust core is an essential component of the military carrier telephone equipment, and vast quantities have been produced to exacting specifications.*

During the war there has also been a great increase in the production of quartz crystals from high quality raw quartz for the control of frequencies to very fine limits in spite of extreme working conditions of temperature and vibration in aircraft, tanks, ships, etc. (see also page 131). Despite diminishing supplies of skilled labour, production has been enormously increased.

MAXIMUM DEMAND METER.

Fig. 50 illustrates a meter recently introduced for the measurement of maximum demand in kilovolt-amperes. It consists of a kWh meter associated with one, or alternatively two, kVAh meters in one case. The kWh meter has a register reading in kWh and a demand indicator showing maximum demand in kW. The kVAh meters are provided with a register reading in kVAh and a demand indicator showing maximum demand in kVA.

It is well known that a kWh meter will also register kVAh over a limited range of phase displacement without serious error. By the use of three meter elements a range of power factor between 0·95 leading to zero lagging

*G.E.C. Journal, Vol. XIII., No. 2, August, 1944, p. 90, "Magnetic Dust Cores," by G. R. Polgreen.

can be covered, and the error in kVA measurement will not exceed $\pm 2{\cdot}5$ per cent. If two meter elements are used, the working range will cover 0·95 leading to 0·6 lagging for the same limits of error.

the system is a rectangular ten-way moulded connector, the plug half being wired to a multicore cable and the socket half to the appropriate service. The connector is also used for the inter-connections behind panels

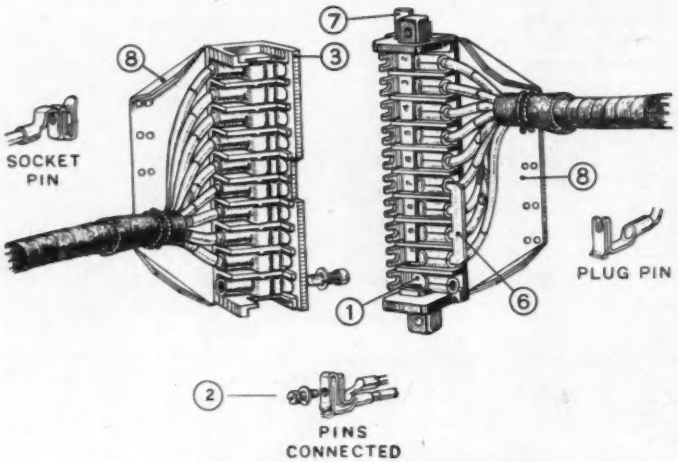


Fig. 51.—Moulded connector used in aircraft wiring systems.

AIRCRAFT WIRING SYSTEMS.

The Company was one of the first to examine the possibilities of pre-fabricated aircraft wiring and in conjunction with Messrs. Vickers-Armstrong developed a system for the Wellington bomber which has been installed in all these machines since 1940 and also in all Warwicks. Originally designed for double pole, the system is equally efficient with single pole earth return. The basis of

and in junction boxes. In place of the original 14 types of multi-core cable containing from 10 to 43 cores, to-day four standard 10 core cables adequately cover all main circuits. Circuits up to 60 amps. are supplied by paralleling wires by means of a metal comb (fig. 51—(6)).

The construction of the connector block, which is $3\frac{1}{8}$in. by $2\frac{1}{8}$in., is shown in fig. 51, which depicts the original type with a moulded

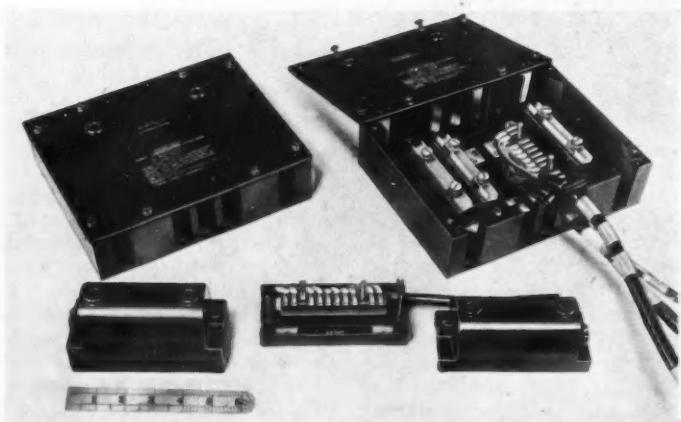


Fig. 52.—Half-tray and two-tray junction boxes used in conjunction with the " Strip " system of aircraft wiring.

housing (3) and a metal backplate (8). It comprises two halves forming the plug and socket. The plug section contains ten plug terminals (1) held in position by a retaining slide (7) which passes through slots in the bakelite dividers. Plug and socket terminals are soundly connected together by a screw (2). The ten units when screwed in position secure-

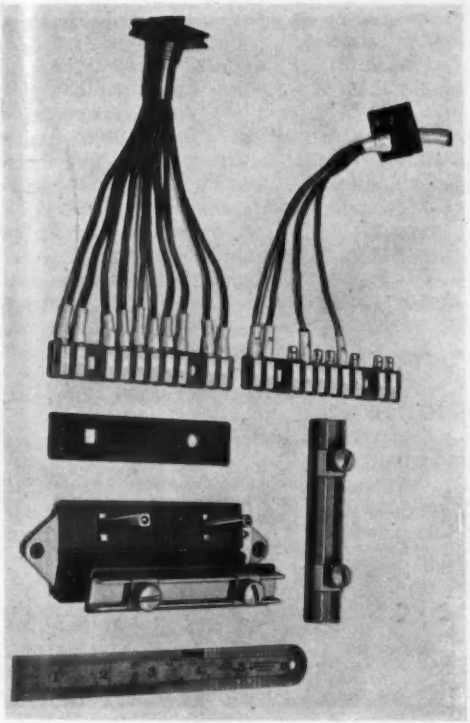


Fig. 53.—Standard components of the "Strip" system for aircraft wiring, showing a 10-core cable assembly, and a strip-connected local cable assembly.

ly lock the socket and plug halves of the strip together, the cable ends being protected by a rubber sleeve and anchored to the connector plate by waxed thread. The later type of connector has rubber inserts to prevent entry of moisture and a separate locking screw.

The connector blocks are held on a panel in the aircraft by a special rack, an adjustable clamp being used to secure the blocks against the end bracket; when the bracket is in position in the aircraft, all circuits can be readily identified and the locking screws can be used as test points.

The main advantages of the system are ease of installation and maintenance, availability of spare circuits for modification or repairs and the use of one connector in the entire system. Due regard has been paid to weight and space and the system is applicable to all types of aircraft.

STRIP SYSTEM.

In collaboration with the M.A.P. a wiring system has been devised which includes a minimum of machined and moulded parts. The result is the "Strip" system installed on the Barracuda and Firefly amongst other aircraft. As in the system described above, a single type of connector is used in conjunction with multi-core cables. The connector consists of a narrow strip of bakelite round which are wrapped 10 terminals, each with a soldering lug. A stainless steel spring inside each terminal ensures a low resistance contact when two or more strips are pressed together; the rubber covered wire is clamped by projections on the tags, while there are small lugs at the other end to which a commoning bar can be soldered. The strips are mounted on tray pillars inside junction and distribution boxes (fig. 52). There are three standard junction boxes for 40, 80 and 120 terminals in which each tray pillar will take up to 5 strips, thus allowing 5 cables to be connected together without the necessity of looms or jumper connections. In addition, there is a small die cast box when only 10 or 20 connections are required.

Fig. 53 shows standard components of the strip wiring system.

PLASTIC INSULATION FOR WIRES AND CABLES.

During the war great progress has been made in the use of plastic and synthetic material for insulating wires and cables. Only for certain vital cables of the highest quality is any considerable amount of natural rubber now used. For dielectrics the natural rubber content has been greatly reduced, while for sheathing, synthetic rubbers only are used. Besides synthetic rubbers, plastic insulation is widely used, the most important being Polyvinal chloride (P.V.C.) which has proved highly satisfactory both as a dielectric and sheathing. After the war it is probable that synthetic rubbers and plastic insulation will find their respective uses in conditions to which they are inherently suited.

RADIO FREQUENCY CABLES.

The increased use of radio frequency cables for war purposes required that they should be suitable for higher voltages and frequencies,

thus precluding rubber insulation which involves high loss. The alternative air dielectric cable with low loss supports of synthetic material was impracticable where flexible cables were required, or for very high voltages. Polythene is in every way suitable and is now used exclusively for such work. Much research was done in developing a means of extruding this material and several million yards of polythene insulated cable have been supplied, a very large range of types and sizes being now available.

An air dielectric cable with distrene supports has also been developed, the stringent electrical and physical tests necessary during this period having been carried out in conjunction with the Research Laboratories.

INSULATION OF WIRES.

In the insulation of wires the shortage of natural silk has been met mainly by the use of two groups of rayons: cellulose acetate and regenerated cellulose. None of the substitutes is quite equal to silk but each has certain advantages.

Wires insulated with enamel and fine paper have proved highly suitable for many purposes, especially in the finer sizes. Pigenam, a plastic-enamelled wire of special quality, can be used where ordinary enamelled wire needs a protective covering of cotton or varnished paper, thus affording a better space factor.

Glass fibre has been developed as a substitute for asbestos in the insulation of wires and strips. It possesses the advantages of high electric strength, resistance to heat, moisture and abrasion with a good space factor; it is resistant to most acids and will operate at temperatures at which cotton, silk or enamel would be quickly destroyed.

FITTINGS FOR OVERHEAD TRANSMISSION LINES.

Improvements have been made in fittings for overhead transmission lines. Assembly has been simplified, mechanical and electrical efficiency increased, there is no interference with the lay of the conductor, and soft core or hollow conductors are not subjected to undue pressure nor is there any tendency towards internal collapse.

MOULDED INSULATION.

Even before the outbreak of war moulded insulation products were finding an ever increasing field of application and this process has been enormously accelerated by the demands of the Services. In a great many instances these demands have involved the production of mouldings of extremely complicated designs and of work of a high degree of accuracy. Experience in these directions has, in consequence, been usefully extended. A notable feature has been the very extensive development of a process of injection moulding which has been most helpful in the production of the more complicated forms of moulding required. Much experience has also been gained in the use of the newer forms of plastics, such as polymethylmethacrylate and polystyrene. The shortage of labour has been an incentive to the extensive mechanisation of moulding presses; the experience thus gained should prove of great value in post-war production.

POWDER METALLURGY.*

Further applications have been found for G.E.C. Heavy Alloy‡ in the general engineering field, mass balancing being one of the most important.

A range of tungsten/copper and tungsten/silver alloys, which find considerable application as electrical contact materials, has been developed and put into production.

BATTERIES.

Investigations have resulted in a great improvement in uniformity of voltage and behaviour of individual cells, essential as a result of the demand for high tension batteries of smaller size and increasingly high voltages. With this, a higher standard of intercell insulation and sealing has been necessitated by demands for batteries capable of withstanding arduous climatic conditions.

In some types increased efficiency has been obtained by the adoption of the "flat" or "layer" type of construction, while there has been some development of the well-known inert technique.

* G.E.C. Journal, Vol. XIII., No. 1, February, 1944, p. 3. "Powder Metallurgy," by S. V. Williams.

‡ G.E.C. Journal, Vol. XI., No. 4, August 1941, p. 223, "G.E.C. Heavy Alloy," by G. H. S. Price, S. V. Williams and C. J. O. Garrard.

Relay Interlocking Power Signalling Control

By F. HORLER, M.I.R.S.E.

The Siemens and General Electric Railway Signal Co., Ltd.

INTRODUCTION.

THE advancement of railway signal engineering during recent years has been towards certain definite objectives: the better performance of apparatus, extended range of the signalman's control, increased facility of operation and additional safety. Although these purposes might seem unattainable without higher costs, there was always the collateral consideration of the economy these improvements could directly or indirectly provide.

So far as the item of increased safety is concerned, it must be acknowledged that the standard reached was already high, but the availability of electrical appliances has enabled protective measures outside the limitations of early mechanical signalling devices to be commonly applied. The other progressive aims are not altogether inseparable from each other, because the extension of the range and the reduction of effort in operation are made possible by the use of power and the improvements in the apparatus design; and it may be said that there are now available more engineering facilities for increasing the territory controllable from a central point than can generally be put to practical use. The distance from a cabin at which points may be worked manually in Britain is restricted by the Ministry of Transport Requirements to 350 yards, but there is no limit fixed for power operation, which is, in itself, often a justification for using power.

LEVER FRAMES.

Most people are familiar with the appearance of the mechanical lever used for operating

Fig. 1.—Power frame with 36 levers. On pulling the levers the vertical shafts below rotate and, by means of segmental bridge pieces between contact springs, open or close circuits as desired. The electro-magnet lever locks operate on horizontal bars behind the levers. If a frame of this type were substituted for the panel in fig. 3 it would require to be at least four times as long as the one here illustrated.

points and signals manually. When power operation was introduced the new apparatus followed the convention by using a lever frame, though naturally much reduced in size. A lever in a power frame is essentially a circuit controller, opening or closing contacts as required in the operating circuits of points and signals.

The contacts can be plainly seen in fig. 1 where they appear in vertical rows below the levers. Each lever is itself controlled so that its movement is subject to other levers being in appropriate positions either to ensure sequences (*e.g.*, the putting of points in their proper positions before signals can be cleared) or to prevent conflicting conditions (*e.g.*, giving two clear signals which would authorise movements which could result in a collision). This is known as lever interlocking. In addition the lever is controlled by non-occupancy of track circuits, proving that there is no train where the presence of one would make the movement of the lever dangerous, and also to ensure that its function has been completely carried out (*e.g.*, that the relative points had responded fully or the relative signal had returned to its stop aspect).

When lever interlocking is carried out mechanically the mechanism in the power frame is similar to, though smaller than, that of the mechanical frame, and it is a matter of necessity that the levers should be built together in a rigid frame. There has been a growing practice, not universal but extensive, to employ electrical means to accomplish lever interlocking; each lever being equipped with an electro-magnet which releases the lever lock when supplied by energy through contacts of other levers in appropriate positions. In this way it would be possible—if it were also desirable—to dispense with the rigid frame and to construct each lever as a self-contained unit, connected to other levers by circuit wires only. The levers might be themselves power operated; in fact, this has been done on the London Passenger Transport Board, where compressed air is used to drive the levers under the control of a signalman. If, instead of levers, electrical relays are employed, and made subject to the same control to which lever operation is subjected, relay interlocking takes form.

RELAY INTERLOCKING.

The term interlocking which was formerly used strictly in reference to the control of a lever by the position of other levers as already explained, is now commonly used to embrace all the controls applied to a lever. This is indicated in the broad definition given in the British Standards Institution Glossary of Signalling Terms, *viz.*, "An electrical or

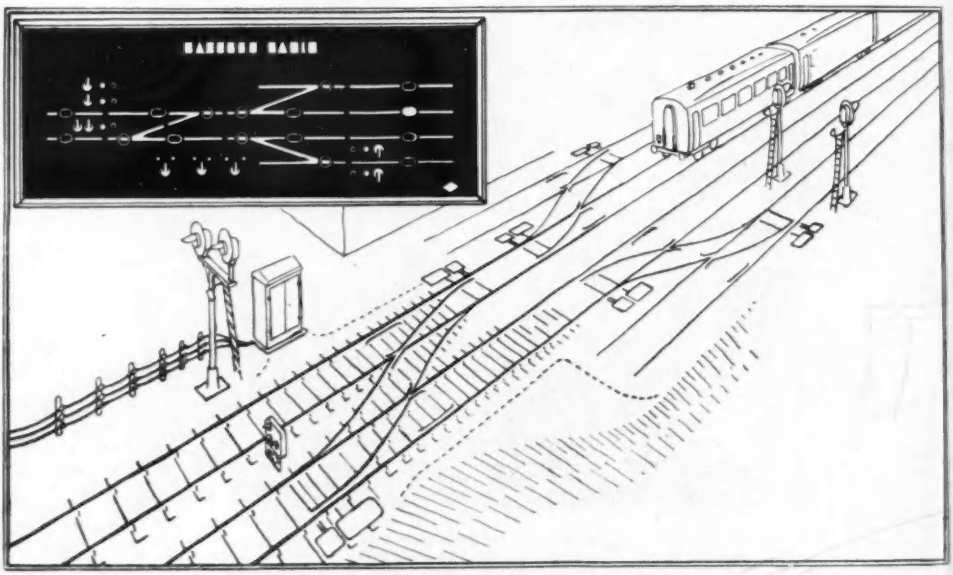


Fig. 2.—Layout of a railway junction with (inset) panel diagram.

mechanical means of making the operation of one piece of apparatus dependent upon certain predetermined conditions being fulfilled by other apparatus." The wider sense of the term is necessary in the understanding of relay interlocking.

The retention of interlocking (in its original sense as between lever and lever) in power levers; not only is less effort required to move a lever, but there is less walking from lever to lever because the power frame is smaller and within easier reach. There were reasons, as explained above, why the design of the power frame took the conventional form, but it was not logical that the development of power operation should end there.

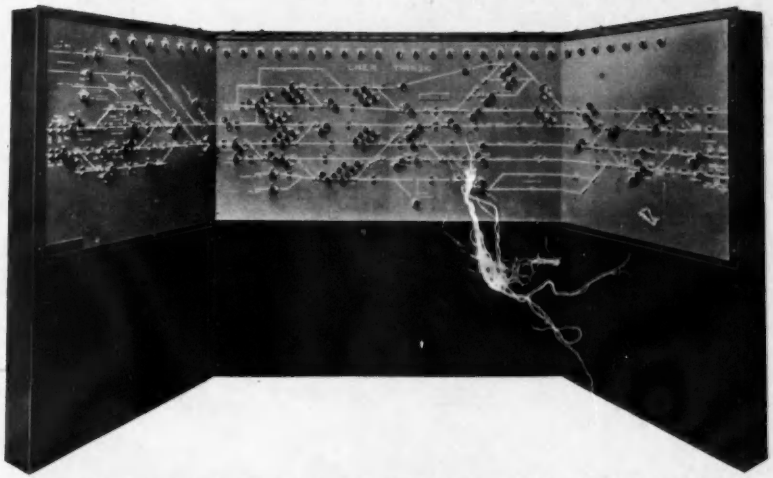


Fig. 3.—The panel illustrated was the first of its kind constructed for use in the United Kingdom. The switches in a row at the top of the panel are for individual operation of points for testing or emergency purposes. To save the crowding which occurs with the use of separate route switches where there are so many possible routes, all future panels will in such cases have rotary selection switches.

systems of signalling is, for the most part, less for theoretical than for practical reasons. If it were omitted, conflicting clear signals would still be circumvented, for they would be found to require incompatibilities such as a pair of points in both normal and reversed position simultaneously, but the system of wiring to points and signals over long distances and in exposed places at stations and yards is vulnerable to faults caused by crosses and grounds, and it is a wise safeguard, in addition to other proper precautions, to prevent a signalman from initiating a movement that would be irregular.

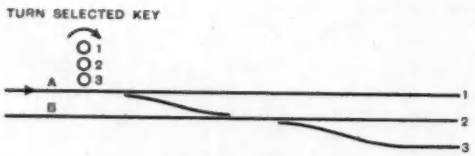
That the man who operates the levers, the signalman, has an important and responsible task will be readily acknowledged. How to make his duties less onerous has been a constant thought of the operating and signalling officers of the railways. Power signalling has been a great factor in mitigating the physical fatigue attendant on the working of mechanical

How much easier and more natural if instead of a row of levers, each of which must, in the signalman's mind, be associated by its number and colour with a pair of points or a signal on the line, there could be a miniature representation of the permanent way with the position of all the points and signals clearly shown geographically, and with small operating keys placed at each signal position. A very extensive control might be brought practically within arm's length and, moreover, the function of each key would be recognised by its location. A glance at fig. 2 will convey the idea graphically; the perspective view depicts a typical track layout, and the inset shows the corresponding control panel which gives a compact picture of everything with which the signalman is concerned.

Having once accepted this idea of operation, a further important development and simplification becomes possible, that is, to consider

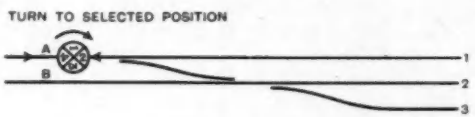
the operation of preparing a path for a train not as the setting of so many individual pairs of points to determine that path, but as a complete route irrespective of the number of points which compose it, and thus to prepare it by the turning of a single key instead of many. The application of relay interlocking is ideal for this purpose since many relays can be controlled by one small key. This method of operation is known as the route interlocking system. There opens up a variety of possibilities in the design and application of the system, which depend largely upon personal choice for adoption, but there are some things generally agreed. First the miniature diagram must be complete in that there are indications on it showing the location of any train, engine or vehicle within its range. Then it must show clearly the position taken up by all the controlled points and the aspects displayed by the signals. The form and disposition of the keys, however, may vary. A few examples will suffice to indicate this. Let us assume a section of railway where movements are possible from one road to any of three others, say, from A to 1 or 2 or 3.

Three switches could be provided at the location A and the appropriate one operated to set the points to road 1 or 2 or 3. The



points having functioned correctly would enable the signal to clear for the train movement to take place.

As an alternative there could be a selector switch which could be turned to the position corresponding to the destination desired, thus :—



As another alternative, the desired route might be selected by a combination of two keys, one at the starting point and one at the destination, defining the route by its two ends A—1 or A—2 or A—3, so :—

Each of these methods is used, and the installation at Thirsk on the London & North Eastern Railway designed by The Siemens and General Electric Railway Signal Company, and the first relay interlocking in the United Kingdom, followed the first example of one key for each route. This is shown in fig. 3.

Relay interlocking is essentially a system of circuits whereby the operation of points and signals can be made in a simple manner with safety. It must make use of all known safeguards such as track locking and detection of points and there must be provision for ensuring requisite sequences and the prevention of the setting up of conflicting routes and signal aspects. Except for the signalman's initial movement of the switch on the panel all the operation must be continued automatically up to the time that the signalman restores his switch—and later if the restoration is premature.

Fig. 4.—Point interlocking and control relay with a total of 36 contacts. The current carried by the contacts is approximately 1 ampere.

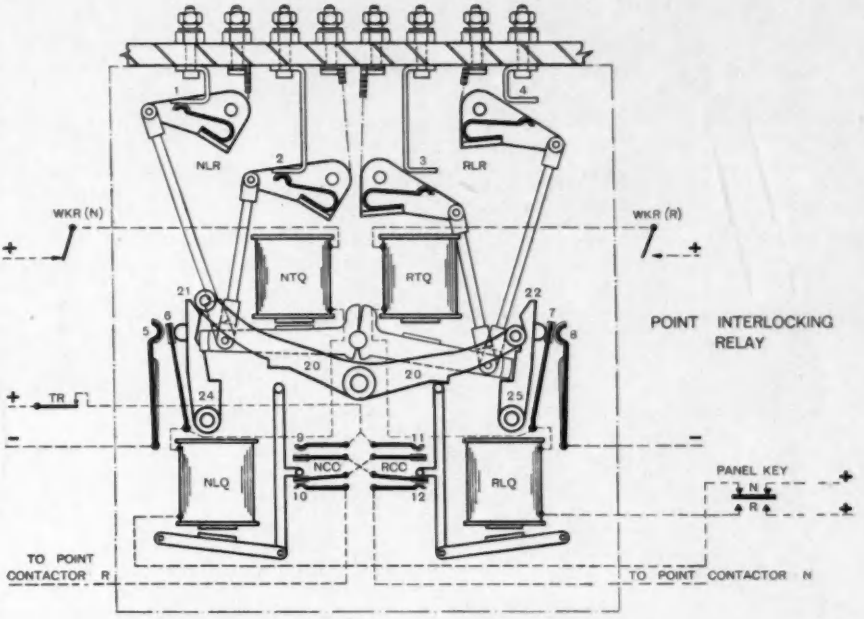


Fig. 5.—Point interlocking and control relay. Schematic view.

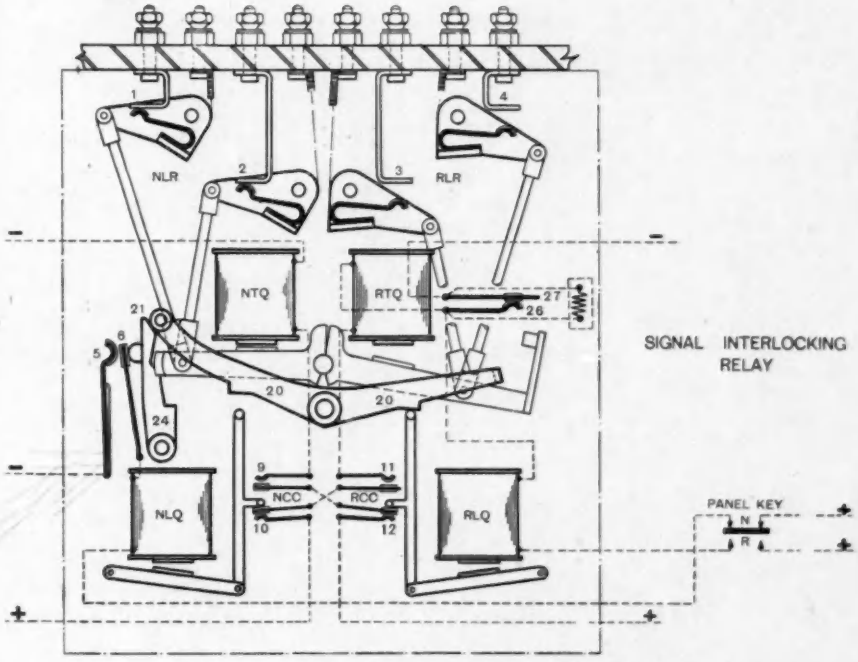


Fig. 6.—Signal interlocking and control relay. Schematic view.

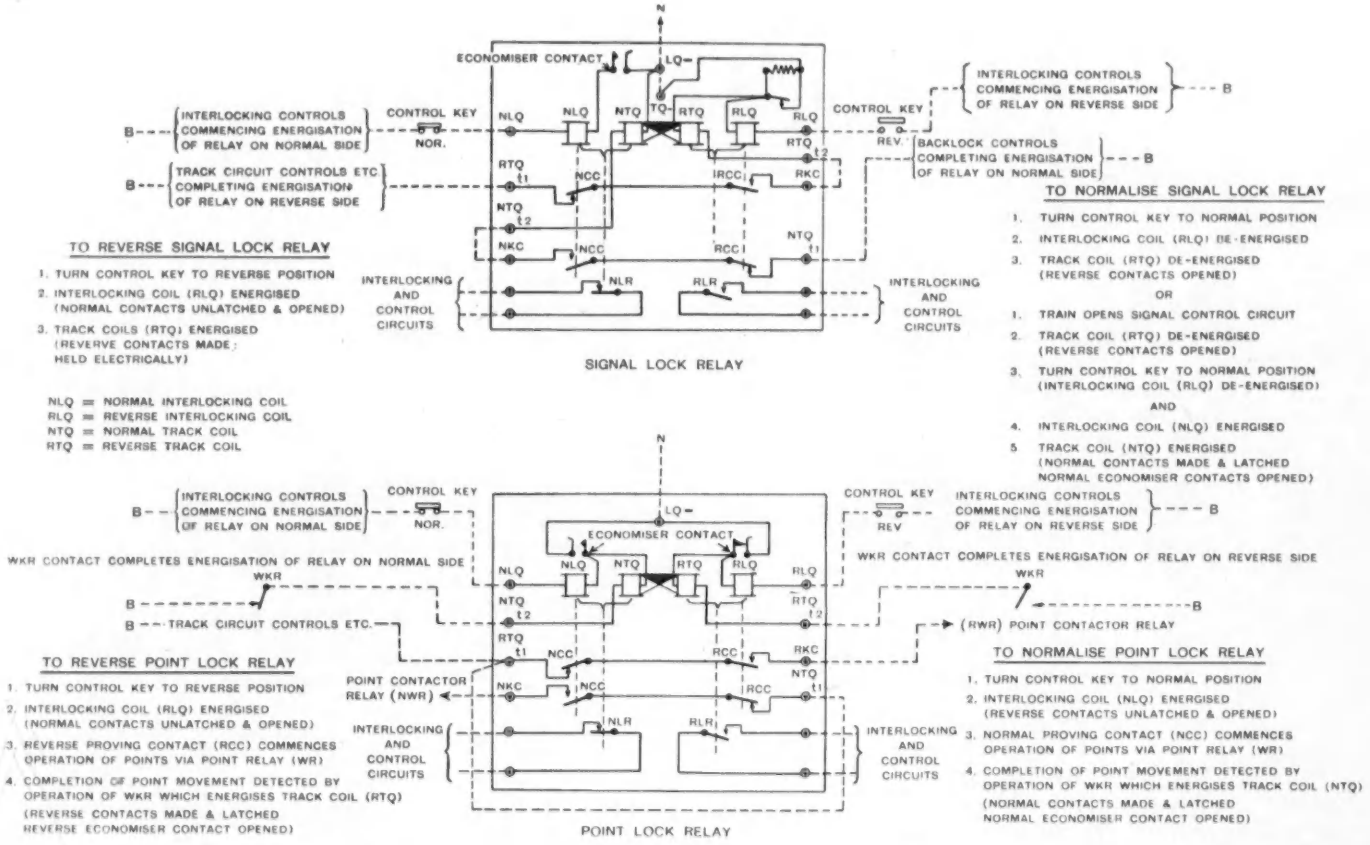

N
ECONOMISER CONTACT
LQ
INTERLOCKING CONTROLS COMMENCING ENERGISATION OF RELAY ON NORMAL SIDE
CONTROL KEY
NOR.
TRACK CIRCUIT CONTROLS ETC. COMPLETING ENERGISATION OF RELAY ON REVERSE SIDE
NLQ
NTQ
RTQ
RLQ
NCC
RCC
IRCC
RKC
NKC
NLR
RLR
INTERLOCKING AND CONTROL CIRCUITS
INTERLOCKING CONTROLS COMMENCING ENERGISATION OF RELAY ON REVERSE SIDE
REV.
BACKLOCK CONTROLS COMPLETING ENERGISATION OF RELAY ON NORMAL SIDE
B
SIGNAL LOCK RELAY
TO REVERSE SIGNAL LOCK RELAY
1. TURN CONTROL KEY TO REVERSE POSITION
2. INTERLOCKING COIL (RLQ) ENERGISED (NORMAL CONTACTS UNLATCHED & OPENED)
3. TRACK COILS (RTQ) ENERGISED (REVERVE CONTACTS MADE; HELD ELECTRICALLY)
TO NORMALISE SIGNAL LOCK RELAY
1. TURN CONTROL KEY TO NORMAL POSITION
2. INTERLOCKING COIL (RLQ) DE-ENERGISED
3. TRACK COIL (RTQ) DE-ENERGISED (REVERSE CONTACTS OPENED)
OR
1. TRAIN OPENS SIGNAL CONTROL CIRCUIT
2. TRACK COIL (RTQ) DE-ENERGISED (REVERSE CONTACTS OPENED)
3. TURN CONTROL KEY TO NORMAL POSITION (INTERLOCKING COIL (RLQ) DE-ENERGISED)
AND
4. INTERLOCKING COIL (NLQ) ENERGISED
5. TRACK COIL (NTQ) ENERGISED (NORMAL CONTACTS MADE & LATCHED NORMAL ECONOMISER CONTACTS OPENED)
NLQ = NORMAL INTERLOCKING COIL
RLQ = REVERSE INTERLOCKING COIL
NTQ = NORMAL TRACK COIL
RTQ = REVERSE TRACK COIL
WKR CONTACT COMPLETES ENERGISATION OF RELAY ON NORMAL SIDE
WKR CONTACT COMPLETES ENERGISATION OF RELAY ON REVERSE SIDE
WKR
TRACK CIRCUIT CONTROLS ETC.
(RWR) POINT CONTACTOR RELAY
POINT CONTACTOR RELAY (NWR)
POINT LOCK RELAY
TO REVERSE POINT LOCK RELAY
1. TURN CONTROL KEY TO REVERSE POSITION
2. INTERLOCKING COIL (RLQ) ENERGISED (NORMAL CONTACTS UNLATCHED & OPENED)
3. REVERSE PROVING CONTACT (RCC) COMMENCES OPERATION OF POINTS VIA POINT RELAY (WR)
4. COMPLETION OF POINT MOVEMENT DETECTED BY OPERATION OF WKR WHICH ENERGISES TRACK COIL (RTQ) (REVERSE CONTACTS MADE & LATCHED REVERSE ECONOMISER CONTACT OPENED)
TO NORMALISE POINT LOCK RELAY
1. TURN CONTROL KEY TO NORMAL POSITION
2. INTERLOCKING COIL (NLQ) ENERGISED (REVERSE CONTACTS UNLATCHED & OPENED)
3. NORMAL PROVING CONTACT (NCC) COMMENCES OPERATION OF POINTS VIA POINT RELAY (WR)
4. COMPLETION OF POINT MOVEMENT DETECTED BY OPERATION OF WKR WHICH ENERGISES TRACK COIL (NTQ) (NORMAL CONTACTS MADE & LATCHED NORMAL ECONOMISER CONTACT OPENED)

Fig. 7.—Descriptive diagrams showing how interlocking and other controls govern the several stages through which the point and signal relays operate.

INTERLOCKING RELAYS

All power signalling involves the discreet use of specially designed relays, and the dependability of these pieces of apparatus is often a measure of the safety of the system as a whole. Relays are used to ascertain whether sections of the railway are occupied or clear, they are used to prove the position taken up by junction points, to repeat the aspects of signals and generally to transfer controls from one place to another. In consequence, the design and manufacture of relays is of considerable importance.

Although there were many types already in use for the various purposes mentioned above, it was decided to make a special one to fulfil the requirements of relay interlocking and so to contrive it that it would reproduce the essential characteristics of a lever. The relay has a complement of 36 contacts which can be divided into several combinations. The size of the relay can be judged by comparing it with the man's hand in fig. 4. The terminal platform, which is detachable from the relay, is so made to enable a relay to be taken out of position for service purposes and replaced by another without disturbing the connected wires, thus not only saving time but possible error in reterminating.

To understand the construction of the relay it must be considered as consisting of two halves, one for the purpose of closing normal contacts and one for the purpose of closing reversed contacts, thus comparing it with the extreme positions of a lever either back in the frame or pulled forward. These two parts are mechanically interlocked so that the normal contacts must be open before the reverse contacts can be closed, and vice versa. To save energy on the relay the contacts of one side when once closed are automatically latched until the opposite side is energised. There is no current in the coils of the relay when the contacts on either side are closed and latched. Figs. 5 and 6 show conventional views of the essential parts and the internal circuits of point and signal relays respectively.

The normal and reverse halves of the relay each include two electro-magnets and armatures; those on the normal side are lettered NLQ and NTQ and those on the reverse side RLQ and RTQ. By referring to fig. 5 the operation of the point relay can be explained. This takes effect in three stages.

1st Stage.

The relay is drawn in its normal position with the contacts 1 and 2 closed. When it is required to reverse the points corresponding to the relay the panel key contact is changed over from the N (normal) to the R (reversed) position. Current is then supplied via the contacts of other relays not shown on the diagram, to the coil RLQ, thence to negative by way of the contact 7/8.

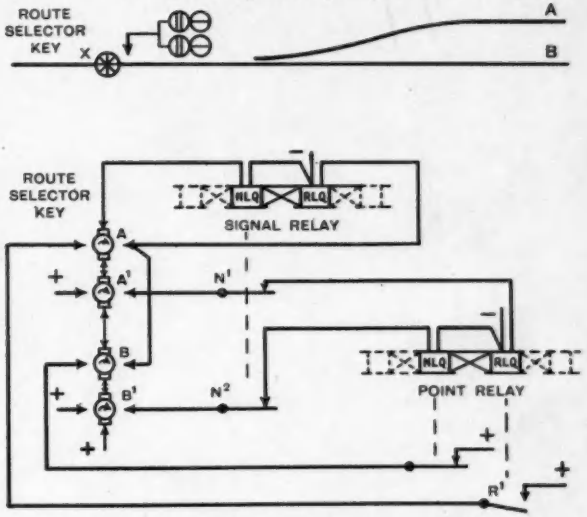


Fig. 8.—Diagram showing the sequence in operation of point and signal relays in route setting systems.

This circuit for coil RLQ is equivalent to the circuit for the interlocking of a lever frame when carried out electrically, and proves that relays with conflicting functions are not operated. The coil RLQ being energised, its armature is lifted and engages the rocking lever 20, pushing downwards the end with the roller 21. This roller pushes outwards the pawl 24 against the contact spring 6, and so releases the armature of the NTQ magnet which drops by gravity, and in so doing opens the normal contacts 1 and 2. The opening of these normal contacts ensures that those other relays with conflicting functions shall remain unoperated. The RLQ armature also opens contact 12 and closes contact 11.

Stage 2.

The actual operation of the associated points now takes place through the control circuit originating at positive, passing over all requisite track circuit relay contacts, here indicated by TR via RCC contact 11

and NCC contact 10 to the point contactor coils R. The point contactor controls the motor of the machine driving the points.

Stage 3.

When the points have been fully operated and locked in position the point detection relay (WKR), which opened its N contact as soon as the points commenced to move, now closes its R contact and completes a circuit for the operation of the RTQ magnet. The armature of this magnet, when raised, closes the reversed contacts 3 and 4 of the relay. In its raised position this armature allows the pawl 25, under pressure from spring 7, to pass beneath it and latch it. Spring 7 separates from spring 8 and opens the circuit to the RLQ and the RTQ so that no current is passed through the relay.

Briefly, the operation of the relay in the three stages ensures first, that conflicting movements are not taking place and cannot take place, then with this assurance causes the points to operate, and only when the points have operated correctly completes its own movement. The lever 20 serves as a physical interlock between the RLQ and the NLQ armatures. Projections above the bosses at the pivot prevent the RTQ and NTQ armatures being lifted together.

The signal relay shown in fig. 6 differs from the point relay in that the reverse TQ armature is not latched in the energised position. This is to permit the automatic restoration of the signal to a "stop" position (by the de-energisation of the relay) by any condition unfavourable to the retention of a "clear" signal arising, such, for instance, as always occurs when a train has passed the signal. Although the armature is not therefore latched, the holding current is reduced through the economising resistance associated with contacts 26/27.

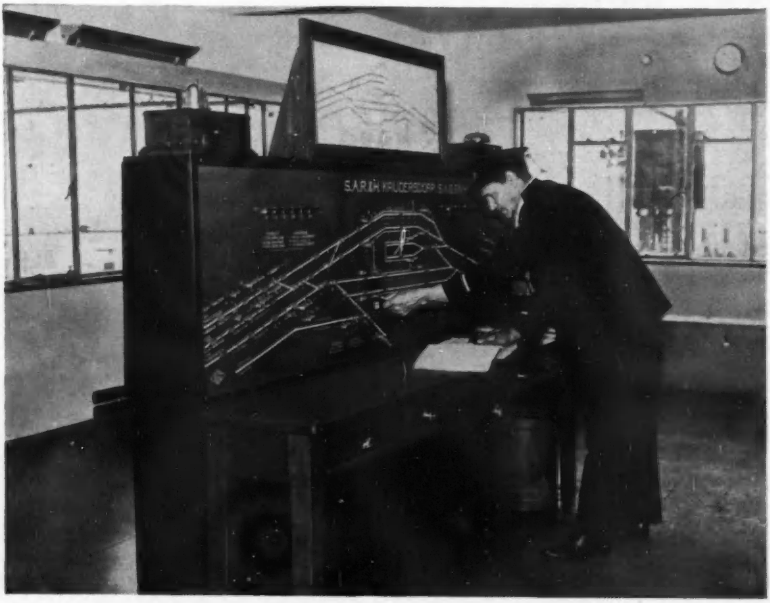


Fig. 9.—Apparatus supplied to Krugersdorp, South African Railways. The convenience and simplicity of panel operation is very well illustrated.

A more detailed explanation of the working of both point and signal relays will be found in fig. 7.

ROUTE SETTING.

The individual operation of the interlocking relays having been followed, the system of route operation in its simplest form can be gathered from fig. 8. Assume that the operator wishes to set up the route X to A, he will turn his selector switch to the A position and the following circuit will be closed. From positive supply over contact A^1, over normal contacts of all relays for signals which should be at stop when the points are moved (here represented by N^1) through the reverse interlocking coil (RLQ) of the points to negative.

When the points have operated and the point relay has made its reverse contacts (R^1), a positive supply is provided over this contact, via A contact of the selector switch through the reverse interlocking coil of the signal relay (RLQ) to negative. The controls exercised by track circuits and point detection are omitted from this diagram for the sake of clarity.

INSTALLATIONS.

The simplicity, compactness and neatness of panel operation with relay interlocking can be gathered from the photographs in figs. 3 and 9. On the former, provision is made for 134 different traffic movements, each controlled by a single key. The width of the panel is 12 feet but it represents a length of 4½ miles of railway. The number of points contained in a route varies from one to seven. The panel in fig. 9 is smaller and contains 43 separate routes, the extent of railway controlled is about 2 miles long.

Fig. 10 is a view of the room below that seen in fig. 9, and illustrates the arrangement of the relays in the system. A rack with shelves similar to the one seen is fixed on the opposite side of the room. On the bottom shelf are the interlocking relays of the type already described. All other relays are such as would be required on any system of power signalling.

In 1939 installations on a very much larger scale were in hand, but were suspended on the outbreak of war. When the time comes for the work to be taken up again and completed, and eventually to be described, it will be seen that the concentration of control by relay interlocking means will go far beyond anything previously done. It is worth emphasising that the limit is not in the means at the disposal of the engineer, but in the measure considered reasonable and practicable by those responsible for operation.

Fig. 10.—An interior view of the relay room at Krugersdorp, South African Railways. The interlocking relays are seen on the bottom shelf. Similar relay shelves stand against the opposite wall; between the two, facing the camera, is the terminal and fuse rack for cables leading from the relay room to the outdoor apparatus.

Fig. 1.—Main building and Control Tower of the Portela Airport, Lisbon.

Lighting of the Portela Airport, Lisbon.

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INTRODUCTORY.

DURING the four years that the greater part of Western Europe was in enemy occupation, the Lisbon Airport naturally attained a position of outstanding importance as virtually the sole point of contact between Continental Europe and the rest of the world.

Despite the great changes in the military situation that have taken place during the past year, the Portela Airport is still, undoubtedly, the most important in Europe, and so far as civil aviation is concerned, is likely to remain so for some years to come. It is situated within 7 miles by road from the Marine Airport of Cabu Ruivo which is used both by Pan-American Airways and British Overseas Airways Corporation.

The illumination of the airport, which forms the subject of this article, was consequently an undertaking of considerable importance, successfully carried out despite the handicaps inseparable from wartime conditions.

LIGHTING EQUIPMENT.

There are four landing runways at Portela Airport, each 1,200 metres in length and 250 metres wide.

The ground on which the airport is situated is reasonably level and there are good approaches to all the runways, so that the layout of the lighting installation did not present any unusual problems.

Wartime conditions dictated the employment of standard equipment throughout, but all the latest detail improvements were embodied in the scheme, and experience has shown that the lighting equipment is entirely adequate for all conditions of weather in which it is practical for large passenger and transport aircraft to operate. It can confidently be

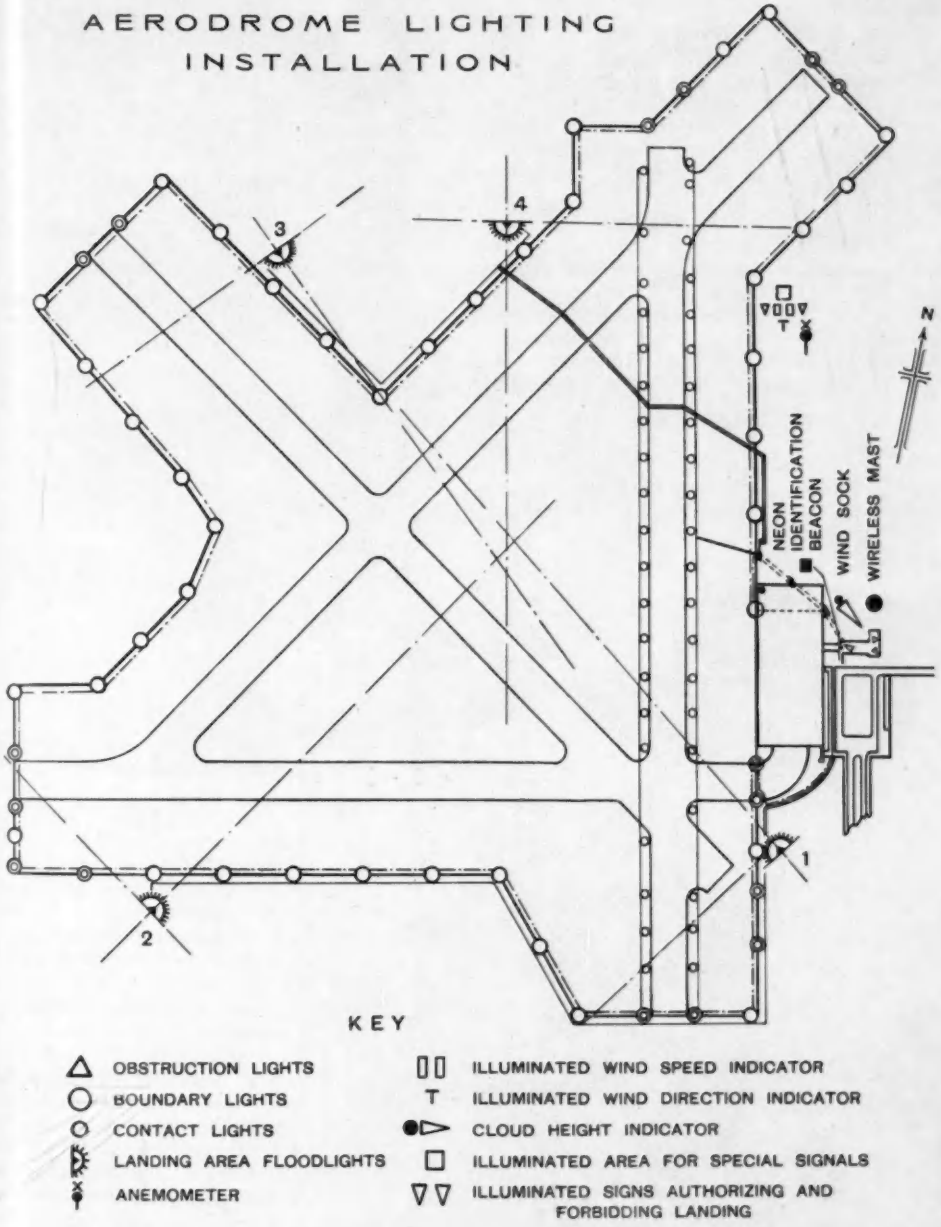


Fig. 2.—General layout of the lighting installation.

claimed that the installation is at least the equal in efficiency of that in any civil airport in the world.

The equipment comprises landing area floodlights, runway contact lights, approach lights, boundary lights, a neon identification beacon, obstruction lights, illuminated indicators for speed and direction of wind, cloud height indicator, illuminated signs for authorising and forbidding landing, and an Aldis signal lamp.

The overall plan of the aerodrome, fig. 2, indicates the location of the various items enumerated above, and the disposition of the runways. The approach lights are not shown in the illustration as they have not yet been installed due to the fact that the extension of the N.-S. and N.W.-S.E. runways to a length of approximately 1,800 metres is still under consideration.

Floodlights.

As can be seen from fig. 2, the airfield is illuminated by four floodlights so placed as to allow for landings in either direction on any of the three runways. The floodlights, one of which is shown in fig. 3, are rated at 6 kW. each, and consist of six 1,000 watt Osram tubular horizon type projector lamps in special glass parabolic trough reflectors. This arrangement gives a wide fan-shaped beam, and makes it possible for one floodlight to illuminate two or more runways. The reflectors are arranged in three vertical tiers, each capable of individual adjustment in the vertical plane, so that the best distribution of light can be obtained if the landing ground is not level (fig. 4). The whole is enclosed in a housing of moulded panels on steel framework which is surmounted by an obstruction light. The housing is sufficiently large to permit servicing of the floodlight under cover, and also contains an auto-transformer to compensate for voltage drop in the supply cable.

The floodlights, incorporating the highest degree of accuracy both as regards the lamps and reflectors, have a maximum intensity of nearly 2,000,000 candle power, and provide adequate illumination for a distance of over 1,000 yards.

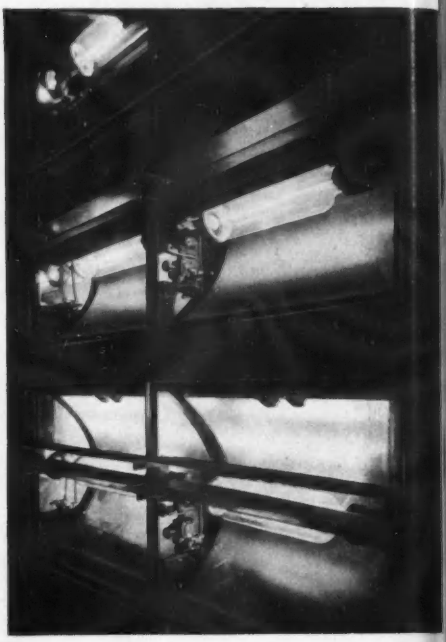


Fig. 4.—The floodlight reflectors.

Fig. 3.—No. 1 Floodlight with the Airport Building in the background.

The floodlight shown in fig. 3 is mounted on a steel structure 13ft. high; this was necessary owing to the grading of the landing ground for drainage. Two of the floodlights are mounted at a height of 34 ft., and in this instance a still higher mounting would have resulted in improved lighting, but this arrangement was not possible as it would have caused serious obstruction to flying.

The photographs reproduced as figs. 5 and 6 give a very good idea of the appearance of the landing ground at night illuminated by these floodlights.

Runway Contact Lights.

The main runway—that is, the runway equipped for fog landings, when the wind is not strong enough to influence landing direction—is equipped with a number of contact lights (fig. 7) in two rows, spaced at 50 metres apart. These lights project only 1 inch above the ground and are fitted with special lenses capable of withstanding a load of 20 tons. They employ the same lamps and operate on the same principle as the boundary lights, but are connected to the isolating transformers through a watertight plug and socket, and spare fittings are kept in store so that re-lamping and servicing can be done indoors and need not entail lengthy obstruction of the runway.

Figs. 5 and 6.—Two views of the landing ground illuminated by floodlights.

Boundary Lights.

The boundary lights operate on a constant potential series system, each light being fed through an isolating transformer in an underground chamber. The lamps used are of the 6·6 volt, 600 lumen, Osram series type, and the fittings consist of a white metal cone surmounted by a special part-silvered glass globe, so that the cone is floodlit in addition to the normal light required by international standard (fig. 8). The height of the fittings is 3 ft., and they are provided with a special weak link, so that they will collapse at ground level if hit by an aircraft. There are, in all, sixty-one boundary lights spaced at intervals of 100 metres round the perimeter of the field. These lights are of the standard amber colour except for two indicating the entrance to the runways, which are green.

Neon Beacon.

The neon beacon (fig. 9) is mounted on the roof of the Control Tower. It consists of six cold cathode neon tubes arranged on a metal framework in the form of a truncated cone, the tubes being inclined so as to ensure the minimum obstruction of light in all directions. The tubes which are hairpin shaped and approximately 14 ft. high, are arranged in three pairs, each pair being fed from a transformer. The three high voltage

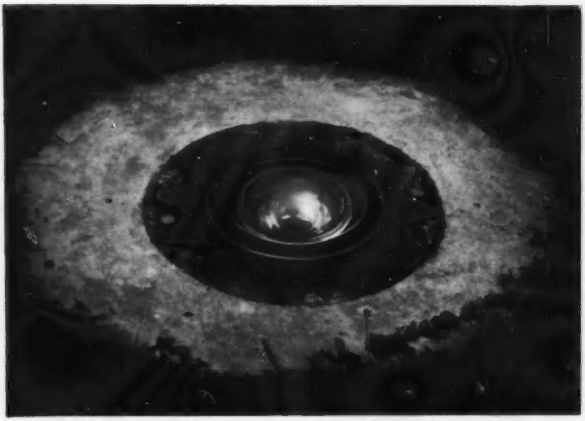


Fig. 7.—Runway contact light.

transformers together with the condensers associated with them for power factor correction purposes, are housed in a tank directly below the beacon, thus keeping the high tension leads between the H.T. transformer and neon tubes as short as possible.

The beacon has an intensity of approximately 3000 candle power and flashes the letter "L," the identification sign for Lisbon, in Morse at intervals of 1½ seconds. The low brightness combined with the large size of the light source give it a range of about 60 miles in fine weather, while presenting no dazzle problem to pilots of aircraft coming in to land.

Wind Direction Indicator.

As can be seen from fig. 10, the wind direction indicator is in the form of a Tee, 20ft. by 20ft., the top surface of which is provided with forty 15 watt lamps under well glasses.

The Tee is accurately balanced and is mounted on ball bearings so that it will indicate true wind direction at ground level when the wind speed exceeds 3 miles an hour.

The design of the fin has been carefully considered to avoid "hunting" which occurred with earlier types of Tee.

Since the photograph was taken a remote control unit has been installed and coupled to the horizontal shaft which can be seen projecting from the base of the Tee. This permits the Control Officer to lock the Tee, or move it to indicate any desired direction in conditions of no wind ; it also incorporates a multicontact switch to give back indication on the control desk.

Wind Speed Indicator.

The wind speed indicator, illustrated in fig. 11, is of the windmill type. As it rotates it operates mercury switches through a centrifugal governor and indicates wind speeds of 5, 10, 15, 20 or 25 k.p.h. to aircraft by means of a simple multiple-lamp sign (fig. 12). Standard 15 watt lamps are used, and back indication is again provided on the control desk.

Obstruction Lights.

These lights are of the standard type and comprise two 60 watt lamps, as each fitting is duplicated. The lamps are under separate well glasses so that the failure of a lamp

Fig. 8.—Boundary light.

can be seen at a glance. All obstructions on and around the airfield, including the floodlights, are marked by these lights which are red in colour. In the case of the floodlights, the obstruction lights are connected in the boundary light circuit, thus effecting a very considerable saving in cable. Fig. 3 shows the twin obstruction lights mounted on top of one of the floodlights.

Cloud Height Indicator.

This consists of a narrow beam searchlight, employing a 500 watt projector lamp, fixed to

throw a beam at an angle of elevation of 45°. At a given distance from the projector there is a clinometer, which can be aligned on the luminous spot on the clouds where the beam strikes them. The scale on the clinometer is graduated to read the height in metres.

Signals.

The portable signalling lamp is used to signal to the aircraft either permission to take off or the contrary. Permission is indicated by a white light, prohibition by a red one. The lamp employed for this purpose is the well-known Aldis signalling lamp.

The illuminated signs authorising and forbidding landing consist respectively of green and red triangular signs, comprising twenty-seven 15 watt lamps of both colours. One of these signs is seen in the rear of the photograph reproduced as fig. 12, from which its mode of use will be self-evident.

Fig. 9.—The Neon Beacon.

In addition to the specific lights already described, there is a floodlit rectangular area, indicated by a hollow square in fig. 2, in

Fig. 10.—"Wind Tee" or wind direction indicator.

which the various internationally agreed signals relating to conditions of ground, direction of circuits, etc., are laid out in white canvas strips.

Provision has been made for the installation of approach lights outside the landing area and in line with the main runway. The function of these lights will be to assist in leading aircraft on to the runway in conditions of bad visibility, but, as already mentioned, these have not yet been installed owing to the possibility of lengthening the runway to 1,800 metres being still under consideration.

It may be added that this will certainly not be too long for some of the heavy types of transport planes which are expected to come into use after the war.

ELECTRICAL SUPPLY AND CONTROL GEAR.

The electrical supply to the airport is at 220 volts, 50 cycles, and is taken from the secondary of two three phase, four wire transformers, 380/220 volts. The incoming supply passes to the eight-unit steel cubicle switchboard shown in figs. 13 and 14, from which it will be seen that the cubicles are provided with hinged fronts.

A schematic single line diagram of the electrical layout is given in fig. 15. Cubicles 1 and 2, shown on the left of fig. 13, control

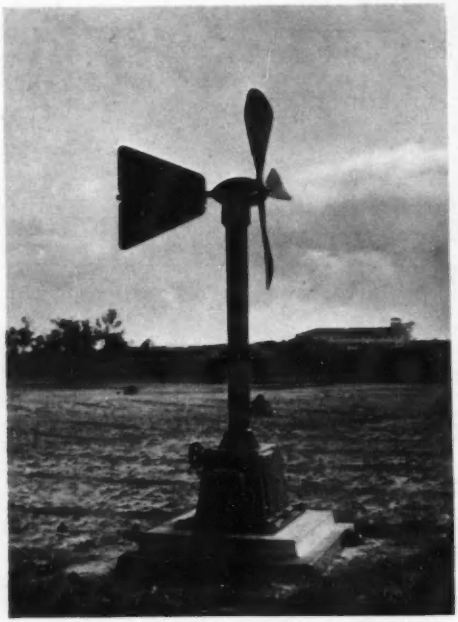


Fig. 11.—Windmill type wind speed indicator.

the incoming feeders, and each is equipped with a 3-pole contactor with local and remote control push buttons, together with the necessary ammeters and voltmeter. Cubicles 3, 4, 5, 7 and 8 control the outgoing circuits to the aerodrome and buildings, and each circuit is controlled by a contactor, operated from a pilot switch, and is protected by fuses. Cubicle 6, which controls the neon beacon, houses a main contactor operated by a pilot switch, a heavy duty flashing contactor and a motor-driven coding machine.

Control Desk.

The control of all the lighting and indicating equipment on the aerodrome is effected from a specially constructed control desk illustrated in fig. 16, the various switches and indicating lamps being situated to the right and left hand side of the Control Officer who is responsible for the operation. Fig. 17 is a detail view of the right hand side of the desk and shows the three rows of switches which control the various items of equipment already described, as well as the wireless supply and the building and apron floodlights. Below each switch is an indicating lamp to show whether the circuit is open or closed. On the sloping front above these switches is a plan of the aerodrome with indicating lamps corresponding to each item of equipment which show whether the particular circuit is alive or not. These lamps are fed from the low voltage side of a small transformer housed in the control desk.

Directly above the plan will be seen the wind velocity indicator which consists of 5

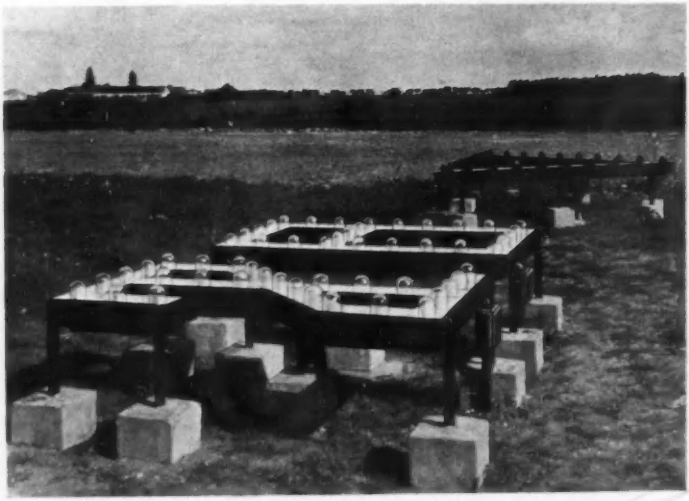


Fig. 12.—Multiple lamp wind speed indicating sign.

lamps marked respectively 5, 10, 15, 20 and 25 k.p.h. which are controlled by a series of relays in the base of the wind speed indicator on the airfield. To the right of the plan is the wind direction indicator, comprising eight lights set in the form of a circle at the cardinal points, which are actuated by an 8-point switch in the Wind Tee.

At the left hand side of the control desk are situated the ammeters for the incoming supply operated from current transformers in cubicles Nos. 1 and 2. There are also a series of opening and closing push buttons and indicating lamps for the main contactors in each of these cubicles.

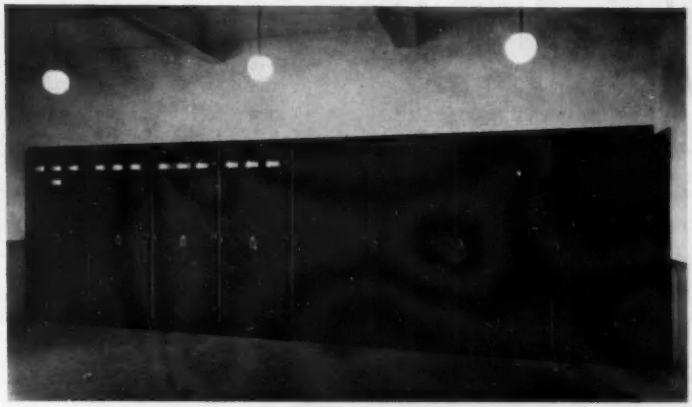


Fig. 13.—Eight-unit cubicle control panel.

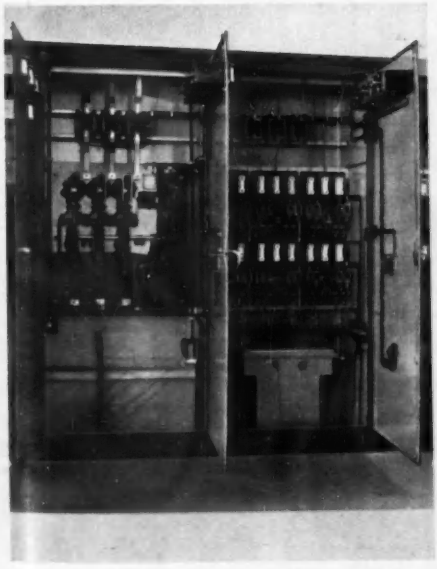


Fig. 14.—Control cubicles with hinged fronts open.

Approach Lights.

In this circuit, in order to compensate for the voltage drop in the cable, the supply will be stepped up through a three phase transformer housed in one of the cubicles of the main switchboard. This higher voltage will then be transmitted through a 3-core cable to a step-down transformer, situated near the point of distribution to the approach lights, to give a low voltage three phase four-wire supply for the approach lights.

Floodlights.

The supply for the four floodlight circuits is taken direct from the main switchboard through a 3-core cable. In this case, compensation for the voltage drop in the 1550 metres of low tension cable is effected by the use of a 6 kVA auto-connected booster transformer, 329/380 volts, located near each floodlight to give a three phase four wire supply.

Boundary and Contact Lights.

Both the boundary and contact light circuits consist of a single core ring main with small isolating series transformers for each light. The ring main is fed from the secondary of a 5 kVA. single phase transformer ; in the case of the boundary lights the ratio is 380/680

volts to supply sixty-one 600 lumen lamps distributed along 5500 metres of cable; for the contact lights the transformation ratio is 380/620 volts, and the transformer supplies sixty-three 600 lumen lamps along approximately 3700 metres of cable. In each case the ring main constitutes a high voltage, constant potential series circuit, the current in which is 6·6 amps. This is fed through the primary side of each series transformer which gives, on its secondary side, an output of 6·6 amps. at 6·6 volts for each light. By this arrangement the failure of a lamp does not affect the remainder of the lamps in the series circuit. Each isolating transformer is contained in a wax-filled, sealed container, the connections being brought out through watertight glands. The main transformer feeding the ring main is housed in one of the cubicles of the main switchboard.

Neon Beacon Flashing Device.

The closing of the pilot switch on the desk closes the main 3-pole contactor in cubicle No. 6 of the main switchboard, thereby starting up a small fractional horsepower motor which drives a character cam. Through a train of gears this cam makes and breaks the

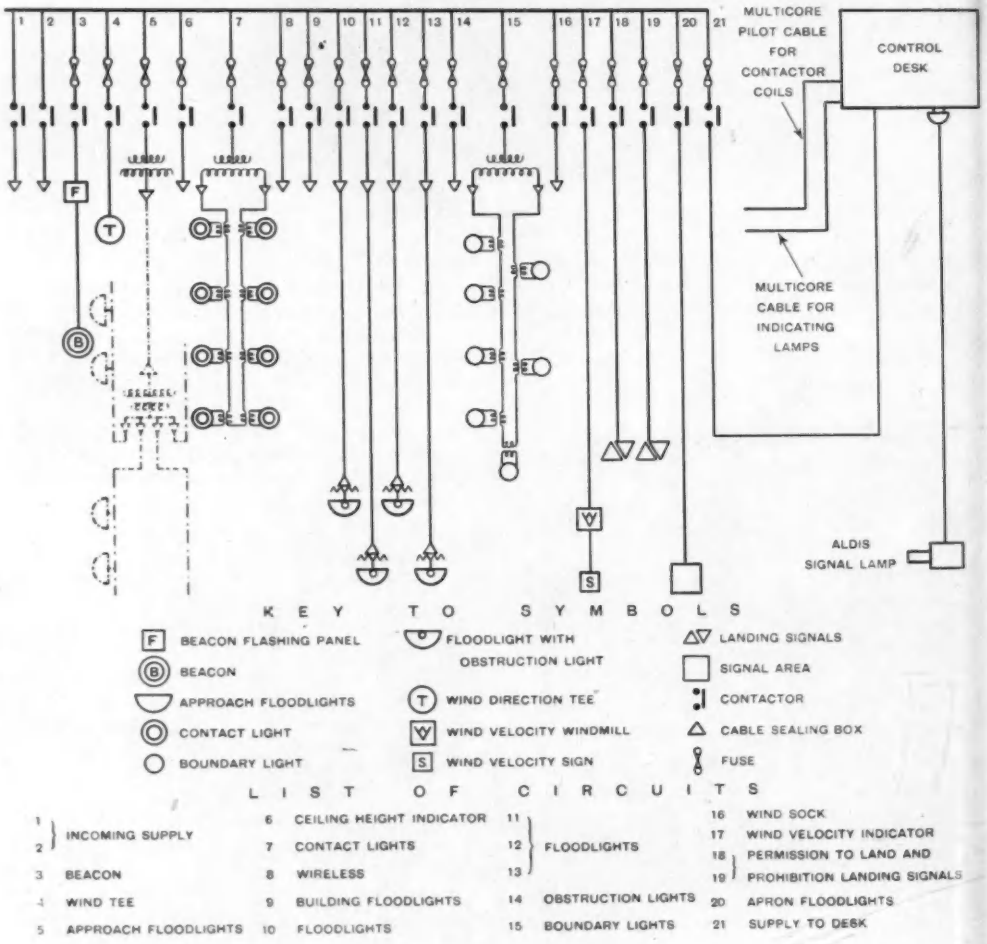
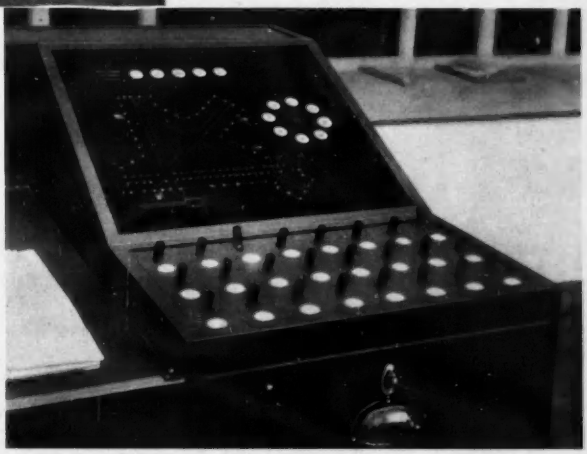


Fig. 15.—Diagrammatic layout of landing area circuits.



Figs. 16 and 17.—(above) Control desk. (right) Detail view of part of control desk.

coil circuit of the heavy duty contactor, and this in turn, controls the main supply to the flashing beacon.

Wind Velocity Indicator.

A general description of the manner in which the wind speed is indicated to aircraft by means of the multiple lamp sign has already been given. It will be sufficient to add here that the centrifugal governor rising and falling with the variation of wind velocity, actuates a series of small contacts which are inter-connected with relays in such a manner as to illustrate the appropriate figures of wind speed on the desk.

Wind Tee.

Under normal circumstances the wind Tee is free to take up any position dependent upon the direction of the wind. When there is no wind, or no more than a negligible breeze, the Tee is set in an arbitrarily agreed position which indicates to the aircraft in which direction to land. It is orientated to this position from the control desk and locked.

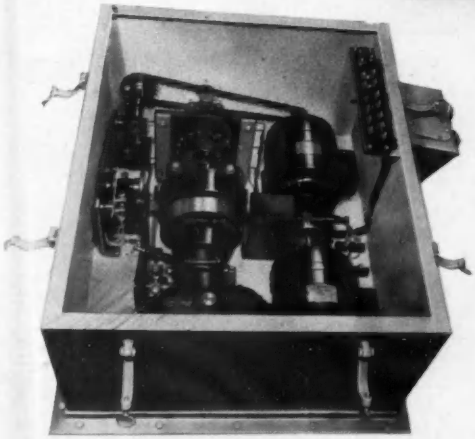


Fig. 18.—Operating mechanism for wind Tee with housing cover removed.

In the mechanism which effects this, the vertical shaft of the wind Tee is coupled to a horizontal shaft through two bevel gearings, ratio 1 : 1. This horizontal shaft is, in turn, coupled to a fractional horsepower motor through a mechanically operated clutch and gearing. On the horizontal shaft, between the clutch and wind Tee, is the 8 point rotary switch which controls the 8 lamps of the direction indicator on the control desk.

The operating procedure is as follows: to bring the Tee to any desired position, the pilot switch is closed, thus putting in the clutch. A push button is then pressed, causing the orientation motor to rotate, which it will continue to do so long as the button is held down.

When the desired position of the wind Tee is reached the push button is released and the Tee will remain locked in that position. To free the Tee it is only necessary to open the pilot switch thus releasing the clutch.

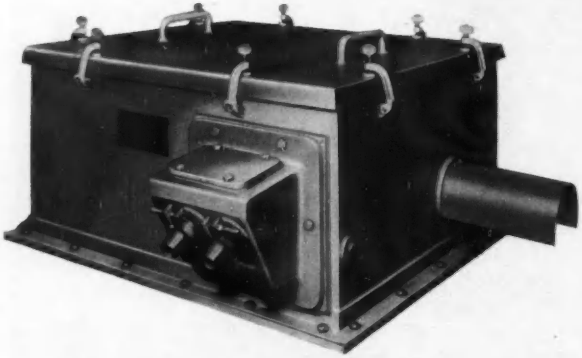


Fig. 19.—External view of weathertight box housing wind Tee operating mechanism.

Fig. 18 shows the box in which the mechanism is housed with the cover removed. The cone clutch is seen to the left and next to it, at the front, the motor which puts the clutch in or out. At the other end, towards the top right hand corner, is seen the orientation motor which turns the Tee through a system of gearing. The box closed, as it would be under operating conditions, is shown in fig. 19.

CONCLUSION.

The entire scheme for the illumination of the airport was devised by the G.E.C. who also supplied the equipment with the exception of the signs for authorising and forbidding landing, and the wind speed indicator, which consist of simple sheet metal trough signs manufactured locally and incorporating fittings supplied by the G.E.C. The main switchboard and the control desk were also made locally and again embody electrical components manufactured and supplied by the Company.

The authors desire to acknowledge the helpful co-operation of the contractors, the Engineering Company of Portugal, Ltd., and of the Directors of the Portela Airport in making available the photographs and much of the material used in the preparation of this article.